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Recreational Development Capacity Study of Six Lakes in the South Riding Mountain Planning District (1986)

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Manitoba
Environment and
Workplace Safety
and Health

RECREATIONAL DEVELOPMENT CAPACITY STUDY OF SIX LAKES IN THE SOUTH RIDING MOUNTAIN PLANNING DISTRICT (1986)

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SUMMMARY

The South Riding Mountain Planning District Board requested that recreational development capacity studies be conducted on twelve lakes located within the Planning District. The Board's goal was to develop guidelines for recreational development such that lake water quality was maintained, that the aesthetic appeal of the area was not impaired and that prospective water based recreational activities could be safely accommodated.

The study commenced in July 1985 as a joint effort between the Board and Water Standards and Studies Section of the Manitoba Department of Environment and Workplace Safety and Health. Board responsibilities included sample collection and provision of required background information. The responsibilities of Water Standards and Studies Section included sample analysis, data interpretation and report preparation. Interpretive aids and applied procedures included assessment of trophic status, identification of problem nutrients, development and validation of phosphorus budgets and calculation of cottage capacities and boat capacities.

The results obtained from seven of the lakes studied were particularly successful from the viewpoint of achieving study goals (Beck, 1987). Additional work was required on the remaining five lakes. Additional study of these five lakes plus study of a sixth, Wolf Lake, was undertaken during 1986. The 1986 results are discussed in the present report.

Both Otter Lake and Little Jackfish Lake were found to be hyper-eutrophic. This means that the water quality generally is not considered suitable for body contact recreational purposes. Nitrogen availability controlled algae and weed growth in Little Jackfish Lake while phosphorus controlled production in Otter Lake. Significant conflicts between various water based recreational activities are unlikely at present rates of utilization of these waterbodies. Valid phosphorus budgets again could not be developed for either lake. However, the advanced state of eutrophy rendered both lakes unsuitable for permanent recreational developments. Therefore, it was recommended that further recreational development of a permanent nature be permitted on neither Otter Lake nor Little Jackfish Lake.

Sandy Lake was confirmed to be an eutrophic lake. The water quality generally is considered suitable for recreational purposes except during major algae blooms. Phosphorus availability controlled algae and weed production in the lake. Significant conflicts between various water based recreational activities are unlikely even at the present moderate to heavy rate of utilization by boats. Similar to Otter and Little Jackfish Lakes, a valid phosphorus budget could not be developed. The state of eutrophy and the advanced level of recreational development about the lake suggested that it has already been developed to a point near its potential maximum. Therefore it was recommended that further recreational development not be permitted on Sandy Lake.

Both Dummy Lake and Stewart Lake were found to border on the eutrophic state. The water quality of each was considered suitable for recreational purposes except during severe algae blooms. Phosphorus availability controlled algae and weed production on these lakes. The phosphorus loading rates to both lakes were very excessive. Due to background phosphorus loadings, the water quality of both lakes was expected to continue to deteriorate over time. Both lakes have the potential to accommodate additional development without detectably affecting water quality. Thus it was recommended that future development at Dummy Lake not exceed a lake total of 109 additional cottage equivalents. These latter were to be calculated at the rate of 1 cottage = 0.147 residences = 2.22 campsites/day use sites. Future development at Stewart Lake was recommended not to exceed a lake total of 131 addtional cottage equivalent units. These were to be calculated at the rate of 1 cottage = 0.147 residences = 1.54 campsites/day use sites. Due to very excessive background phosphorus loading rates, it was further recommended that potential developers and prospective recreational investors be advised that occasional water quality problems can be anticipated.

Wolf Lake was found to be a moderately eutrophic waterbody and the water quality generally was suitable for recreational purposes except during severe algae blooms. Phosphorus availability controlled algae and weed growth in the lake. The rate of background phosphorus loading was very excessive and would cause rapid deterioration in water quality conditions unless ameliorative actions were taken. Due to the excessive rate of phosphorus loadings and the rate of water quality deterioration, it was recommended that permanent recreational developments not be permitted on the lake. Temporary developments, however, could be accomodated to a lake maximum of 105 campsites/day use sites.

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1.0 INTRODUCTION

The South Riding Mountain Planning District (Figure 1) is comprised of four municipal jurisdictions, including the Rural Municipalities of Clanwilliam, Harrison, Strathclair and the Local Government District of Park (Municipal Affairs, 1985). The Planning District abuts the south perimeter of Riding Mountain National Park. The District has a proven attraction for cottagers and other recreationers.

The influx of cottagers and other recreationers to what had been a predominately agricultural area, as well as the demand for additional development, resulted in some resource allocation conflicts. These conflicts included the traditional rights of land owners respecting usage and development, the public demand for additional recreational opportunities and development, and the general citizen's concern that the environment not be degraded (Beck, 1987). A study begun in 1985 at the request of the Planning District Board* sought to develop a scientifically sound compromise between the three areas of conflict (Ibid). Recommendations were to be made regarding further recreational development, thereby allowing land owners to

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* The Planning District Board is composed of representatives from each municipal jurisdiction, Mr. Wally Dmyterko (Secretary-Treasurer) and Mr. Terry Pearce (Land Use Planner, Department of Municipal Affairs).

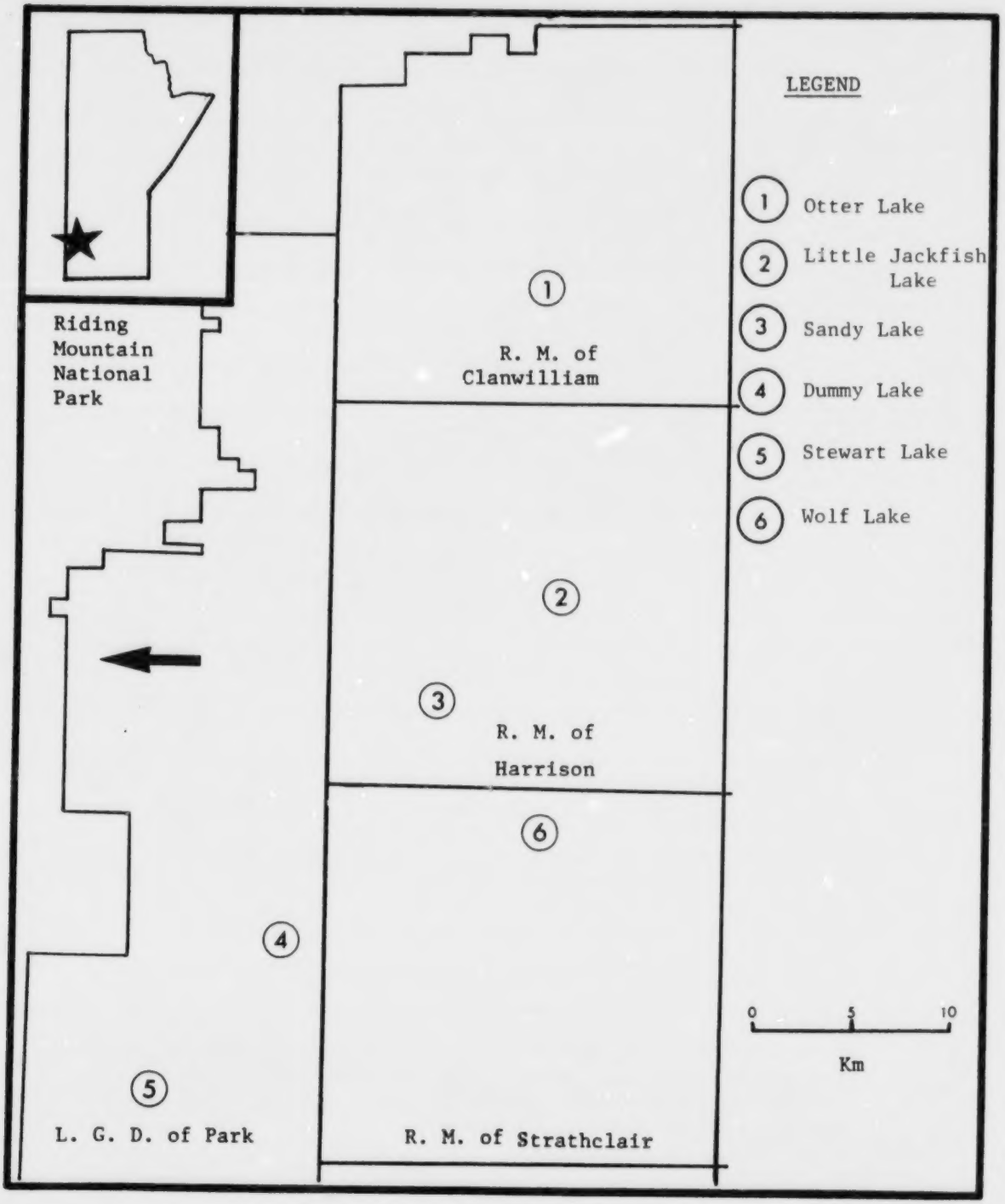

Figure I: The South Riding Mountain Planning District.

consider subdivision of property. The key criteria upon which the recommendations were to be based included the maintenance of environmental quality, aesthetic considerations and the safety of recreationers.

The 1985 study successfully developed recommendations for seven of the twelve lakes considered (Beck, 1987). However, further effort was required in order to finalize developmental guidelines for five of the lakes (Ibid). These five lakes, Otter, Little Jackfish, Sandy, Dummy and Stewart, as well as a sixth previously not considered, Wolf Lake, constitute the focus of the present paper. Specific objectives established for the 1985 study were modified slightly in order to more accurately reflect the specifics of the 1986 effort. Accordingly, the specified objectives of the present study were:

1. To identify the trophic status of the six lakes examined;
2. To develop specific recommendations with respect to the cottage carrying capacity of the six lakes examined.

Similar to the original study, the present paper was not intended as an itemized management proposal detailing the exact nature of future developments. Again, it was intended to imply that further ameliorative action could be undertaken to improve existing water quality.

2.0 METHODS

The methods adopted for the present study were refined only slightly from Beck (1987). However , the entire methodology is reproduced hereinafter for the sake of report selfsufficiency.

2.1 Rationale

The primary objective of the study was to develop specific recommendations regarding the cottage carrying capacity of six lakes located within the South Riding Mountain Planning District. The key criteria included environmental quality, public safety and aesthetic considerations. The criteria, though interdependent, required slightly differing avenues for evaluation.

Maintenance of environmental quality is perhaps the most basic or critical of the criteria. The literature (Vollenweider, 1968; Vallentyne, 1974) leaves little doubt that overdevelopment along aquatic systems results in an accelerated rate of eutrophication . Accelerated eutrophication, or rapid aging of a lake, is caused by increased nutrient loading and is manifested by such symptoms as numerous algae blooms, excessive macrophyte growth and frequent fish die-offs. Classic whole lake experiments have implicated phosphorus overabundance as the trigger for accelerated eutrophication (Schindler et al., 1971; Schindler, 1977). Applying these principles to the present study, maintenance of environmental quality required that phosphorus loadings from potential and/or existing developments could not significantly exceed the background rate of phosphorus loading.

This meant that emphasis had to be focused upon the development of an accurate phosphorus budget for each of the lakes. Permissible rates of development could then be calculated using appropriate margins of safety or error.

Safety considerations were viewed from the perspectives of public health and mechanical or physical safety. The health perspective focused upon the prevention of potential surface water contamination by human wastes. The strategy for this endeavour is already well established and is embodied in the various regulations pertaining to the proper installation and maintenance of sewage disposal systems such as septic fields and holding tanks. The mechanical safety perspective focused upon prevention of boat collisions and near collisions. This was achieved by applying "crowding" criteria developed by Thomas (1983).

Aesthetic considerations are particularly difficult to evaluate. The strategy adopted in this report was based upon the assumption that current conditions, though not ideal, were acceptable to recreationers of the area. This required that existing quality be quantified such that the full range of conditions which might be experienced were determined. This meant that the trophic status of each lake had to be assessed. The strategy also required that the existing environmental quality not be permitted to deteriorate. This aspect was included as a prerequisite in the error or safety margin factor of the permissible rate of development calculations.

2.2 Field Procedures

A rigorous water sampling regime was implemented on each of the lakes in order to assess the validity of the phosphorus budget. The primary intent of the field sampling program was to provide an estimation of the mean total phosphorus concentration [P] at an accuracy level indicated by a mean standard error of less than 10% of the mean. Hence, the water sampling regime was based on a strategy of stratified random sampling (Cassie, 1971). Based upon previous investigations (Water Standard and Studies, unpublished data), the number of sampling stations was set originally at three, but was increased to four in order to compensate for a reduced summer sampling period during 1986. Summer sampling frequency was set at once weekly and fall and winter sampling frequency was set at once per term. (Sampling station locations are illustrated in Appendix I.) Sampling depths were determined by considering random numbers a percentage of total depth at each station.

Samples at depth were collected using a 2.2 L pesticide grade acrylic Kemmerer sampler. Depth integrated chlorophyll "a" samples were collected at a maximum of twice the Secchi depth by using a Water Standards and Studies sampler. Instruction in proper sampling technique was provided to Mr. Bob Philipation and Mr. Michael Popp, both students resident in the area who collected the summer samples (144 samples). Fall and winter sampling (48 samples) was conducted by Water Standards and Studies.

All samples were shipped by scheduled bus service to the W. M. Ward Technical Services Laboratory so as to arrive within

twenty-four hours of collection. Analyses were performed at the laboratory according to procedures described by Sorba et al. (1980).

2.3 Identification of the Problem Nutrient

A nutrient will be consumed by aquatic vegetation at a rate proportional to the need for that nutrient (Rast and Lee, 1978). Hence, the growth of aquatic vegetation is limited by the nutrient which is available to it in the minimal quantity relative to its needs for growth or reproduction (Ibid). The nutrient most likely to limit productivity can be determined by a "demand:supply" ratio (Vallentyne, 1974). Alternately, the nutrient which is present in large quantities during periods of excessive aquatic vegetation growth is not limiting the growth of that macrophyte (Rast and Lee, 1978).

The demand:supply ratio may be quantified on the basis of actual vegetational requirements. The atomic ratio of nitrogen:phosphorus (i.e. N:P) present in mixed phytoplankton averaged 16:1 (Redfield et al., 1963; in Rast and Lee, 1978). The atomic ratio for algae common to ponds and lakes in the south-eastern United States averaged 24:1 (Rast and Lee, 1978). Converting the atomic ratios to mass or weight (atomic weight of nitrogen = 14.01; atomic weight of phosphorus = 30.97), yields a mass N:P ratio of 7.24 mg N:1 mg P for mixed phytoplankton and 10.86 mg N:1 mg P for algae, respectively. This meant that N:P mass ratios less than the 7.24 to 10.86 range indicated that nitrogen was the limiting nutrient. Alternately, N:P mass ratios greater than the 7.24 to 10.86 range indicated that phosphorus was the limiting nutrient.

Assuming that all nitrogen and phosphorus present in the water during the summer could theoretically be utilized by aquatic vegetation, a ratio of total Kjeldhal nitrogen (TKN) to total phosphorus (TP) would yield a theoretical mass N:P ratio. However, not all of the total nitrogen and phosphorus present are in forms readily available for use by aquatic vegetation. Cowen and Lee (1976) demonstrated that up to 30% of the total phosphorus can be converted to usable phosphorus (i.e. soluble orthophosphate*) in about 20 days. Cowen et al. (1976) showed that up to 70% of organic nitrogen (i.e. total Kjeldhal nitrogen) can be converted to usable forms (ammonia, nitrate and nitrite) in 35 to 50 days. Application of these qualifiers ((TKN x 0.70)/TP x 0.30)) modified the N:P ratio to yield a potentially available mass N:P ratio. A third estimation of the mass N:P ratio was derived from Hutchinson's (1957) estimate that 10% of total phosphorus present in natural water is comprised of soluble orthophosphate (i.e. readily available to aquatic vegetation). Utilizing the sum of ammonia, nitrate and nitrite and the qualified phosphorus, (TP x 0.10) yields a calculated mass N:P ratio.

Among the mass ratios considered (i.e. theoretical mass ratio, potentially available mass ratio and calculated mass ratio) only the calculated mass ratio was found to have utility for the

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* The soluble orthophosphate fraction was not determined in the present study because field preservation techniques are cumbersome and even relatively short terms of storage of preserved samples (i.e. <8 days) yield wide fluctuations in analytical results (El-Shaarawi and Neilson, 1984).

study area (Beck, 1987). Calculated mass ratios derived for each of the six lakes were accordingly compared to the 7.24 to 10.86 range in order to determine which nutrient limited growth.

2.4 The Phosphorus Budget

The phosphorus budgets for the South Riding Mountain Planning District lakes were developed with the aid of a variety of models and data sources. The calculation process was itemized (Table 1) and discussed in a step by step fashion after the manner of Hough, Stansbury and Michalski Limited (1980).

Step 1:

Estimation of the gross drainage basin area is a standard hydrological procedure (Gray, 1970) wherein the high points of land surrounding the lake are outlined on a topographic map. It is assumed that both surface water and groundwater flow downhill as indicated by topographic contour lines. The gross drainage areas for the lakes were measured with an Alpha p-27 polar planimeter. The watersheds were not segregated by land use type as recommended by Hough, Stansbury and Michalski Limited (1980) since the results indicated that the proximity of tilled agricultural land to the lakes' shoreline was of greater significance than its extent in the watersheds.

Steps 2 and 3:

Estimation of lake surface areas is a standard limnological procedure (Welch, 1948). Surface areas were measured by planimetry on 1:50,000 NTS maps.

TABLE 1: CALCULATION PROCESS FOR THE SOUTH RIDING PLANNING DISTRICT LAKES PHOSPHORUS BUDGETS.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	x 10 m^2
2.	Lake Surface Area (Ao)	x 10 m^2
3.	Surface Area of Other Lakes in A (Ao_1)	x 10 m^2
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	x 10 m^2
5.	Lake Volume (V)	x 10 m^3
6.	Lake Mean Depth ($Z = V/Ao$)	m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	x 10 m^3/yr
10.	Flushing Rate ($p = Q/V$)	times/yr
11.	Areal Water Load ($qs = Q/Ao$)	m/yr
12.	Retention Coefficient ($R = 13.2/13.2 +qs$)	
13.	P Loading Rate for Precipitation (L_{Pr})	41 mg/m^2/yr
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	x 10 mg/yr
15.	P Export Coefficient (E)	23.3 mg/m^2/yr
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	x 10 mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S=L_S \cdot Ao \cdot days$)	x 10 mg/yr
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	x 10 mg.
18.	P Contribution per Capita Year (S)	8.0 x10^5 mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	capita years
24.	P Contribution from Campground ($J_A'=S \cdot N_{CY}'[1-R_S]$)	x 10 mg/yr
25.	Number of Cottages (N_C)	units
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}"=P_C \cdot N_C+P_D \cdot N_D$)	capita years
30.	P Contribution from Occupants ($J_A"=S \cdot N_{CY}"[1-R_S]$)	x 10 mg/yr
31.	Total P from Artificial Sources ($J_A = J_A'+J_A"$)	x 10 mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	x 10 mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	mg/L

Step 4:

The surface areas of the lakes with proportionately small watersheds are excluded from estimations of drainage basin area due to the dynamics of evaporation (Hough, Stansbury and Michalski Limited, 1980).

Step 5:

Estimation of lake volume is a standard limnological calculation based upon lake contour maps and planimetry (Welch, 1948). Contour maps of Sandy, Dummy and Stewart lakes were provided by Manitoba Natural Resources*. Contour maps of Otter, Little Jackfish and Wolf lakes were developed by Water Standards and Studies from soundings conducted in late October, 1985 and 1986 (Wolf Lake). A Furuno Mark IV unit was used for these echo soundings.

Step 6:

Estimation of mean depth is a standard limnological calculation (Welch, 1948).

Steps 7 and 8:

Estimates of net annual runoff and net annual evaporation rates for Thomas Lake were provided by Mudry** (pers. com.; Appendix II(a)). Since Thomas Lake is central to the Planning District, the runoff and evaporation rates were extrapolated to all lakes of the Planning District.

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* Courtesy of Brian Yake, Resource Technician, Southwestern Fisheries Region; Manitoba Natural Resources.

** N. Mudry, P. Eng. Director of Planning, Water Resources Branch; Manitoba Natural Resources.

Steps 9, 10 and 11:

These calculations are standard load estimation procedures (Hough, Stansbury and Michalski Limited, 1980).

Step 12:

The empirical formula for estimating the relative amount of phosphorus unavailable for dispersion through the water column was provided by Dillon (no date) in Hough, Stansbury and Michalski Limited (1980). The equation replaces that proposed by Dillon and Kirchner (1975).

Steps 13 and 14:

Atmospheric contribution of phosphorus can be very significant in lakes with small drainage basins (Schindler et al., 1976). Values reported by Schindler et al. (1978) ranged from 24 to 53 mg/m^2/year for the Experimental Lakes Area near Kenora, Ontario. Experimental measurements of aeolian phosphorus contributions conducted near Brandon, Manitoba (Appendix II(b)) indicated loading rates up to 82/mg/m^2/year (M. Bennett, pers. com.*). Considering the values reported for the Experimental Lakes Area, it was deemed not unreasonable to adopt the arithmetic mean of the Brandon values (i.e. 41 mg/m^2/year) for the present study. Estimation of the total atmospheric contribution to each lake was calculated as the rate per square metre multiplied by total surface area of the lake.

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* M. Bennett, Special Projects Coordinator, Air Standards and Studies, Manitoba Environment and Workplace Safety and Health.

Steps 15 and 16:

Dillon and Kirchner's (1975) mean total phosphorus export coefficient for a sedimentary watershed devoted to mixed forest and pasture usage was adopted for the present study. The total natural phosphorus contributed by the watershed was then estimated by the export coefficient multiplied by total area of the drainage basin. Provision for excluding the phosphorus fraction retained in the water columns of upstream waterbodies after the manner of Hough, Stansbury and Michalski Limited (1980) was not made, because the bulk of water movement to lakes within the study area appeared to be by means other than streams (i.e. by overland drainage and groundwater flows).

Step 16(a):

This step was applied only to lakes where anaerobic conditions were either observed (Otter) or imminent (Wolf). It is based upon reports by Vollenweider (1975), Dillon (1975) and others that a net release of phosphorus from lake sediments occurs during anoxia. A mean of Vollenweider's (1968) estimates of daily phosphorus releases from sediments (L_S = 9.5 mg/m^2/day) has been adopted for the present study. Duration of anoxia was estimated by assuming a freeze-up date of November 1, 1986, date of first infiltration of spring meltwater (hence, cessation of anoxia) as March 31, 1987 and onset of anoxia as mid-way between freeze-up and observed anoxia (Otter Lake at December 6, 1986) or mid-way between imminent anoxia and first meltwater infiltration (Wolf Lake at February 20, 1987).

Step 17:

The total phosphorus supply from natural sources may be estimated by summing contributions from the drainage basin outflow and from the atmosphere.

Step 18:

The value recommended by Hough, Stansbury and Michalski Limited (1980) has been adopted.

Step 19:

Surficial deposits of the Planning District are primarily glacial and glacial-fluvial in origin (Jenkins, 1970). The deposits generally consist of coarse materials such as sand, gravel, cobble and boulders as well as finer materials such as silts and clays (Ibid). This heterogeneity infers that soil retention coefficients of total phosphorus may differ substantially even on a very localized basis. Therefore, a relatively medial coefficient, that for silty sand, was adopted from the work of Brandes et al. (1974).

Step 20:

The estimate of campground site units available was derived by Water Standards and Studies following site inspection during summer, fall and winter sampling periods. Factors considered included actual use observed, comments provided by Mr. Wally Dmyterko (pers. com.), facilities available, area available for use and site aesthetics.

Step 21:

An estimate of the mean number of persons per camping unit was not available for either the Planning District or Manitoba in general. The present estimate was derived from the Hough, Stansbury and Michalski Limited (1980) mean of 4.30 capita years at permanent homes, multiplied by 0.352, the mean Western Region campsite occupancy ratio (Manitoba Natural Resources, 1985). Although the mean campsite ratio may be somewhat high for campgrounds of the Planning District, its present use is justified as a way of accounting for loadings due to beach day users and both summer and winter angling activity.

Step 22:

The 1986 season length was estimated on the basis of weekends from May 4 to June 22, and daily thereafter to September 1 (inclusive).

Steps 23 and 24:

Formulae for these calculations were derived from Hough, Stansbury and Michalski Limited (1980).

Step 25:

Counts of the cottages present at each lake were provided by Mr. Wally Dmyterko (pers. com.). Note that in some instances (example, Sandy Lake), cottages equipped with holding tanks have been excluded from the total for the lake. This is because holding tanks effect a net export from the watershed of that cottage's total phosphorus load (Hough, Stansbury and Michalski Limited, 1980).

Step 26:

The absence of specific data for Manitoba necessitated adoption of the values provided by Hough, Stansbury and Michalski Limited (1980).

Step 27:

Residences were defined as occupied homes located within approximately 250 metres of the lake shore. Counts were provided by Water Standards and Studies.

Step 28:

The values provided by Hough, Stansbury and Michalski Limited (1980) were adopted.

Steps 29, 30, 31, 32 and 33:

Calculations were performed according to formulae presented by Hough, Stansbury and Michalski Limited (1980).

2.5 Budget Validation

Budget validity may be assessed either by actual observation or by theoretical means. Since temporal constraints prevented actual measurement of spring phosphorus concentrations over a series of years, actual spring observations could not be used for budget validation. Theoretical budget validation was achieved by calculations drawn from the literature. The process involved algebraic manipulation of established formulae in order to isolate

the spring phosphorus concentration as a variable. The equation was then solved by substitution of measured values for remaining variables.

The classic equation defining the summer chlorophyll a concentration ([Chla]) to spring total phosphorus concentration ([TP]) relationship in north temperate lakes developed by Dillon and Rigler* (1974) was:

$$\text{Eq. 1a:} \quad \log_{10}[\text{Chla}] = 1.449 \log_{10}[\text{TP}] - 1.136$$

The equation may be manipulated to isolate the [TP] variable as follows:

$$\text{Eq. 1b:} \quad \log_{10}[\text{TP}] = (\log_{10}[\text{Chla}]+1.136)/1.449$$

A second equation defining the [Chla]-[TP] relationship in north temperate, shallow mixed lakes was recently developed by Riley and Prepas (1985)*. This equation was:

$$\text{Eq. 2a:} \quad \log_{10}[\text{Chla}] = 1.251 \log_{10}[\text{TP}] - 0.680$$

The equation may be manipulated to isolate the [TP] variable as follows:

$$\text{Eq. 2b:} \quad \log_{10}[\text{TP}] = (\log_{10}[\text{Chla}]+0.680)/1.251$$

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* [Chla] and [TP] are expressed as mg/m^3.

Validation using the Dillon and Rigler (1974) and Riley and Prepas (1985) formulae assumes that chlorophyll a production is neither unduly inhibited nor significantly enhanced. The data suggested that some enhancement or inhibition had occurred on certain lakes. Therefore, it was necessary to test the accuracy of chlorophyll a values with respect to interdependent parameters. Carlson's (1977) indices based upon summer values for chlorophyll a, total phosphorus and Secchi disk values were adopted for this purpose. An average of the three indices (per lake) was calculated and the single occurrence of an index value beyond the limit of $\pm$10% of average was considered arbitrary cause for rejection*. This meant that chlorophyll a concentrations were unsuitable for budget validation on lakes where the range of TSI indices exceeded 20% of an average value.

Assuming that chlorophyll a concentrations were deemed suitable for validation purposes, analytical and regression uncertainties required the setting of acceptable range limits. An acceptable range about the predicted spring phosphorus concentrations (Table 1), was based upon analytical uncertainties and statistical probability*. This meant that the 10% analytical uncertainty at 0.01 mg/L (Sorba et al., 1980) corresponded to a $\pm$ 20% range.

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* Justification for arbitrary usage of the "10%" value is based in the statistical axiom that two units of standard deviation correspond to a probability of approximately 95.4%.

Acceptable range limits about the calculated theoretical phosphorus concentrations (equations 1(b) and 2(b)) were derived from the correlation coefficients of Dillon and Rigler (1974) and Riley and Prepas (1985). These required uncertainties of $\pm$ 5% and $\pm$ 17%, respectively. Phosphorus budgets were considered valid when predicted spring phosphorus concentrations fell within the acceptable range as defined by equations 1(b) and 2(b).

The error bounds for theoretical validations are of necessity quite wide. An alternate approach to budget validation considers water column phosphorus concentrations during late fall and winter. This approach is based upon observations of local pothole lakes published by Barica (1977). Generally, he observed that total phosphorus concentrations were greatest prior to spring breakup (i.e. prior to ice melting and consequently prior to the growth of aquatic vegetation and the proliferation of plankton) and that they declined over the summer months as nutrients became trapped within the tissues of the aquatic biota. During fall and winter months, phosphorus was restored to the water column from organic detritus and the sediments by both aerobic and anaerobic mechanisms. Relevant to the present study, however, was the observation that summer phosphorus concentrations differed from winter concentrations. Furthermore, fall and winter concentrations better approximated pre-breakup maximums than did summer values. This meant that fall and winter concentrations observed during the present study were better suited for estimation of spring concentrations. This estimation, derived

from actual data, could then be used as a check upon the empirically derived prediction of total phosphorus.

Model validation using observed fall and winter values was achieved by first calculating the means of observed fall and winter concentrations for each lake. An acceptable range was drawn from the defined intent of the sampling program to provide an estimation with a mean standard error of less than 10% of the mean. This intent effectively permitted a $\pm$20% range (i.e. 2 σ) about the observed mean value. Predicted total phosphorus values within $\pm$20% of the observed mean value therefore indicated validation of the budget.

2.6 Trophic Status

An understanding of aquatic systems can often be enhanced by application of broadly descriptive terms. One of the more scientifically useful terms pertains to the trophic status, or degree of enrichment and productivity* of a particular waterbody. Three terms are generally used. Oligotrophic refers to unenriched waters of low productivity, mesotrophic refers to moderately enriched waters with moderate productivity and eutrophic refers to very enriched waters which are very productive. Fish kills and excessive aquatic vegetation and algae problems are experienced occasionally in

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* Within the present report, enrichment refers to nutrient availability and productivity refers to biological mass produced.

mesotrophic waters. Fish kills become more common and problem growths of vegetation and algae become ever more extensive as waters become more eutrophic. Clearly defined limits of demarcation between the trophic levels generally are not encountered. Rather, the characteristics of each gradually meld with that of the next level (Vollenweider, 1968).

A variety of definitive indices or classification schemes have been proposed; four of which have gained general acceptance in North America (Rast and Lee, 1978). Two of the indices, (US EPA 1974, Piwoni and Lee 1975), are relatively intensive and involve a number of parameters not measured during the present study. Hence, they were not applicable to the present study. The indices of Vollenweider (1975) and Carlson (1977) were more readily applicable to the present study.

Carlson (1977) developed a numerical trophic state index graduated on a scale of 0 to 100. The index number may be calculated from secchi disk transparency, chlorophyll a or total phosphorus (Ibid). The approximate limit of demarcation between eutrophic and mesotrophic states occurs at 50 units and between mesotrophic and oligotrophic states occurs at approximately 30 units (Ibid). The computational forms of the equation (Ibid) are:

$$\text{Eq. 3.}\quad TSI\ (SD)^{*} = 10\left(6 - \frac{\ln SD}{\ln 2}\right);$$

$$\text{Eq. 4.}\quad TSI\ (Chl)^{*} = 10\left(6 - \frac{2.04 - 0.68\ (\ln Chl)}{\ln 2}\right)$$

$$\text{Eq. 5.}\quad TSI\ (TP)^{*} = 10\left(6 - \frac{\ln (48/TP)}{\ln 2}\right)$$

Vollenweider's (1975) scale (Figure 2) considered a logarithmic relationship between phosphorus loading and mean depth/hydraulic residence time. The process involves plotting phosphorus loading ($g/m^2/yr$) versus mean depth/hydraulic residence time (qS from Table 1). Phosphorus loadings are estimated by the phosphorus budget calculation process (Table 1).

2.7 Cottage Capacity Calculation

The cottage equivalent capacity calculation process has been modified from Hough, Stansbury and Michalski Limited (1980). The process is essentially an extension of the phosphorus budget calculation and has been itemized and discussed in a step by step fashion (Table 2). Phosphorus budget validation is a prerequisite to use of the calculation process.

Steps 1, 2, 3, 4, 5 & 6:

These values have been extracted from Table 1, steps 18, 19, 26, 32, 25 and 23, respectively.

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* Where SD is expressed in metres, Chla is expressed in mg/m^3 and TP is expressed in mg/m^3.

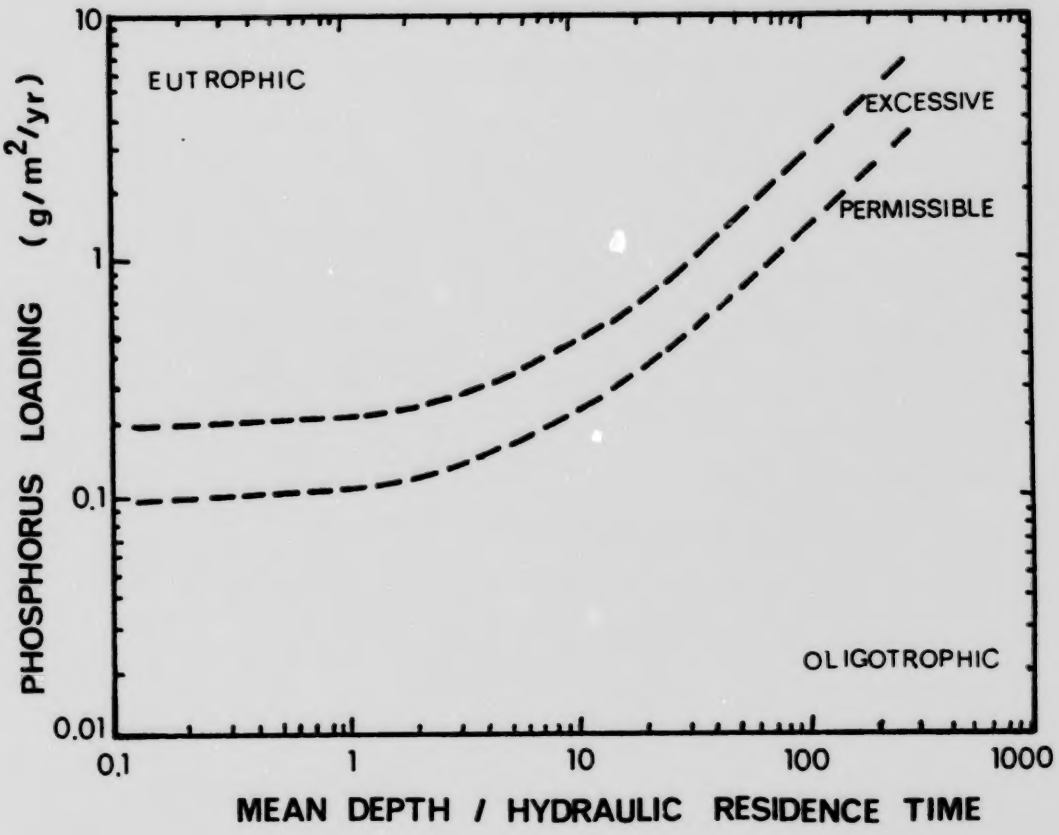

Figure 2: Vollenweider's (1975) trophic state scale.

TABLE 2: CALCULATION PROCESS FOR ESTIMATION OF SOUTH RIDING MOUNTAIN PLANNING DISTRICT LAKES COTTAGE EQUIVALENT* CAPACITY

STEP	PARAMETER	QUANTITATION
1.	P Contribution per capita (S)	8.0×10^5 mg/yr.
2.	Sewage Treatment Retention Coefficient (R_s)	0.63
3.	Capita Years per Cottage (P_C)	0.63 capita years
4.	Total P supply (J_T)	x 10 mg/yr.
5.	Number of Cottages (N_C)	units
6.	Campground Capita Years (N_{CY}')	capita years
7.	Total Campground and Cottage Capita Years ($N_{CY}^2 = P_C \cdot N_C + N_{CY}'$)	capita years
8.	P Contributions from Cottages and Campgrounds ($J_{C1} = N_{CY}^2 \cdot S \cdot [1-R_s]$)	x 10 mg/yr
9.	Significance of Non -J_{C1} Contributions ($K = [J_T - J_{C1}]/J_T$)	
10.	Predicted P (P)	mg/L
11.	Predicted P minus J_{C1} Contributions ($P_1 = P \cdot K$)	mg/L
12.	Analytical Error Associated with P_1 (E_1)	mg/L
13.	Calculation Error Permitted ($E = [E_1/_4]$)	mg/L
14.	Outflow (Q)	x 10 m^3/yr.
15.	Retention Coefficient (R)	
16.	Permissible Cottage and Campground Loading ($J_{CP} = E \cdot Q/[1-R]$)	x 10 mg/yr.
17.	Permissible Number of Cottage Equivalents ($N_{CE} = J_{CP}/[1-rs] \cdot P_C \cdot S$)	units

* The term "cottage equivalent" implies that alternate uses can be readily accommodated within the calculation process by application of appropriate conversion factors. For example, one cottage is equivalent to either 0.147 permanent residences, or to 4.5 campsites.

Steps 7 & 8:

These calculations are standard load estimation procedures (Hough, Stansbury and Michalski Limited, 1980).

Step 9:

This ratio quantifies the relative importance of phosphorus contributions other than those from cottage and campground sources.

Step 10:

This value has been extracted from Table 1, step 33.

Step 11:

The calculation provides an estimate of conditions which might have been extant had recreational development not occurred.

Step 12:

Study objectives required that detectable water quality degradation not occur as a result of future developments. Because water quality was defined in the present study by varied terms which were dependent upon total phosphorus concentrations, non detectable water quality degradation was linked to the analytical error associated with measurement of total phosphorus concentrations. Values cited were derived from the precision and accuracy data of Sorba et al. (1980).

Step 13:

A safety margin of 50% ($E_1/2$) was considered adequate for present study purposes. Note, however, that as 95% confidence limits may be approximated by 2 σ, the permissible calculation error is properly quantified at $[E_1/2]/2$, or $[E_1/4]$.

Steps 14 & 15:

These values have been extracted from Table 1, steps 9 and 12, respectively.

Steps 16 & 17:

These formulae have been modified from Hough, Stansbury and Michalski Limited (1980). Units for Step 17 are rounded off to the nearest whole number.

2.8 Boat Capacity Calculation

Boat capacity calculations or crowding criteria were adopted from Thomas (1983). Boat capacity may be calculated by dividing lake surface area suitable for boating, by the area of water required by each boat for safe and enjoyable operation (Ibid). The present study defined lake surface area suitable for boating as all lake area beyond the 1.5 metre depth contour. Values were obtained during planimetry for lake volume calculations. Thomas' (Ibid) value of average space required per boat (5.28 ha) was directly adopted. Calculated boat capacities were then compared to estimates of maximum current use.

These estimates were computed from the following equation (Ibid):

Eq. 6: $B = (Np \times Qp) + (Nc \times b \times Qc)$*

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* Where B = maximum number of boats on the lake at any one time;

Np = number of parking spaces available to the public, equivalent to Table 1, step 20 "U"'

Qp = number of boats per public parking space; Thomas (Ibid) suggests 0.4;

Nc = number of cottages and residences;

b = number of boats per cottage, the present study adopts the number "1";

Qc = number of cottages with a boat in use at any one time; Thomas (Ibid) suggests 10%-25% and a median figure (17.5%) is adopted in this study.

3.0 RESULTS AND DISCUSSION

Water physicochemical data are detailed in Appendix III.

3.1 The Problem Nutrient

As previously discussed, N:P mass ratios greater than the 7.24 to 10.86 range indicated that phosphorus was the limiting nutrient while N:P mass ratios less than the 7.24 to 10.86 range indicated that nitrogen was the limiting nutrient. The calculated mass ratio (CMR) results permitted lakes of the present study to be arranged into two groups; those above the range and those below the range. These groups corresponded to phosphorus limited lakes and lakes limited by nitrogen, respectively (Table 3).

Table 3: Lakes of the South Riding Mountain Planning District Grouped on the Basis of Nutrient Sensitivity.

LAKES SENSITIVE TO PHOSPHORUS (N:P)		LAKES SENSITIVE TO NITROGEN (N:P)	
Otter	(33.98)	Little Jackfish	(2.13)
Sandy	(22.81		
Dummy	(21.10)		
Stewart	(14.39)		
Wolf	(13.38)		

Placement of each lake in the appropriate group was critical for development of an effective management strategy for each lake. For example, the phosphorus limited lakes (Otter, Sandy, Dummy, Stewart and Wolf) would demonstrate little ecological change with substantial additional loadings of nitrogen. However, even minor additional loadings of phosphorus could effect major ecological changes in this group of lakes. Alternately, lakes limited by nitrogen (Little Jackfish) would demonstrate little impact from phosphorus loadings but would show major changes with additional loadings of nitrogen.

Beck (1987) had reported that nitrogen was the limiting nutrient for Little Jackfish Lake, that phosphorus was the limiting nutrient for Sandy Lake and that Otter, Dummy and Stewart lakes were relatively balanced (i.e. sensitive to loadings of either nitrogen or phosphorus). The sensitivity of Little Jackfish Lake to nitrogen and of Sandy Lake to phosphorus was confirmed by data obtained during the present study (Table 3). However, present data (Table 3) further indicated that Otter, Dummy and Stewart lakes were not balanced as previously suggested (Beck, 1987), but rather were actually limited by phosphorus. Considering that the body of physico-chemical data previously obtained for these lakes was deemed insufficient for some of the purposes of the 1985 study (Ibid), it was reasonable to revise their status in favour of additional data garnered during 1986. Allocation to the "phosphorus sensitive" designation (Table 3) was

also consistent with the current prevailing view that phosphorus is almost exclusively the sole limiting nutrient for prairie pothole lakes (J. Barica*, pers. com.).

3.2 Phosphorus Budgets and Validation

Phosphorus budgets developed for the six lakes under study are presented in Tables 4 to 9. Budgets for Little Jackfish and Stewart** lakes (Tables 5 and 6, respectively) remain unchanged from Beck (1987). However, examination of newer, more detailed topographical maps permitted revised estimates of the drainage basin for Sandy and Dummy lakes. This in turn effected some minor (Sandy Lake) and some major (Dummy Lake) revisions to the original budgets (Ibid) for these waterbodies (Tables 6 and 7, respectively). The budget for Otter Lake was revised by inclusion of phosphorus loadings from sediments during anaerobic conditions (Table 4). The budget for Wolf Lake (Table 9) was developed during the present study. Predicted spring total phosphorus concentrations ranged from 0.107 mg/L for Otter Lake (Table 4) to 0.015 mg/L for Sandy Lake (Table 6.).

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** Typographical errors in volume, mean depth and flushing rate (Beck, 1987) have been corrected in the present paper (Table 8).

TABLE 4: CALCULATION PROCESS FOR THE OTTER LAKE PHOSPHORUS BUDGET.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$1.481 \times 10^8 m^2$
2.	Lake Surface Area (Ao)	$1.016 \times 10^7 m^2$
3.	Surface Area of Other Lakes in A (Ao_1)	$4.25 \times 10^6 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$1.337 \times 10^8 m^2$
5.	Lake Volume (V)	$1.397 \times 10^7 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	1.38 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$4.945 \times 10^6 m^3/yr$
10.	Flushing Rate ($p = Q/V$)	0.354 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.487 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 +qs$)	0.964
13.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	4.166×10^8 mg/yr
15.	P Export Coefficient (E)	$23.3 mg/m^2/yr$
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	3.115×10^9 mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	1.120×10^{10} mg/yr
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	1.473×10^{10} mg/yr
18.	P Contribution per Capita Year (S)	8.0×10^5 mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	30 units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	10.55 capita years
24.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	3.122×10^6 mg/yr
25.	Number of Cottages (N_C)	127 units
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	6 units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}" = P_C \cdot N_C + P_D \cdot N_D$)	105.81 capita years
30.	P Contribution from Occupants ($J_A" = S \cdot N_{CY}" [1-R_S]$)	3.132×10^7 mg/yr
31.	Total P from Artificial Sources ($J_A = J_A' + J_A"$)	3.444×10^7 mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	1.476×10^{10} mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.107 mg/L

TABLE 5: CALCULATION PROCESS FOR THE LITTLE JACKFISH LAKE PHOSPHORUS BUDGET.*

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$6.595 \times 10^6 m^2$
2.	Lake Surface Area (Ao)	$7.857 \times 10^5 m^2$
3.	Surface Area of Other Lakes in A (Ao_1)	$4.520 \times 10^5 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$5.357 \times 10^6 m^2$
5.	Lake Volume (V)	$2.053 \times 10^6 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	2.61 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$1.123 \times 10^5 m^3/yr$
10.	Flushing Rate ($p = Q/V$)	0.055 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.143 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 + qs$)	0.989
13.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	3.221×10^7 mg/yr
15.	P Export Coefficient (E)	$23.3 mg/m^2/yr$
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	1.248×10^8 mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	N/A
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	1.570×10^8 mg/yr
18.	P Contribution per Capita Year (S)	8.0×10^5 mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	2 units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	0.70 capita years
24.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	2.07×10^5 mg/yr
25.	Number of Cottages (N_C)	0 units
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	3 units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}" = P_C \cdot N_C + P_D \cdot N_D$)	12.9 capita years
30.	P Contribution from Occupants ($J_A" = S \cdot N_{CY}" [1-R_S]$)	3.818×10^6 mg/yr
31.	Total P from Artificial Sources ($J_A = J_A' + J_A"$)	4.025×10^6 mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	1.610×10^8 mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.016 mg/L

* Although not limited by phosphorus (Sec. 3.1), the calculation process has been completed for the sake of data consistency.

TABLE 6: CALCULATION PROCESS FOR THE SANDY LAKE PHOSPHORUS BUDGET.*

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$3.868 \times 10^7 m^2$
2.	Lake Surface Area (Ao)	$4.840 \times 10^6 m^2$*
3.	Surface Area of Other Lakes in A (Ao_1)	$3.140 \times 10^6 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$3.070 \times 10^7 m^2$
5.	Lake Volume (V)	$1.918 \times 10^7 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	3.23 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$5.283 \times 10^5 m^3/yr$
10.	Flushing Rate ($p = Q/V$)	0.028 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.109 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 +qs$)	0.992
13.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	1.984×10^8 mg/yr
15.	P Export Coefficient (E)	$23.3 mg/m^2/yr$
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	7.153×10^8mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S=L_S \cdot Ao \cdot days$)	N/A
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	9.137×10^8mg/yr
18.	P Contribution per Capita Year (S)	8.0×10^5mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	5 units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	1.76 capita years
24.	P Contribution from Campground ($J_A'=S \cdot N_{CY}'[1-R_S]$)	5.204×10^5mg/yr
25.	Number of Cottages (N_C)	231 units**
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	4 units***
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}"=P_C \cdot N_C+P_D \cdot N_D$)	162.73 capita years
30.	P Contribution from Occupants ($J_A"=S \cdot N_{CY}"[1-R_S]$)	4.817×10^7mg/yr
31.	Total P from Artificial Sources ($J_A = J_A'+J_A"$)	4.869×10^7mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	9.624×10^8mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.015 mg/L

* Only the contiguous south basin is considered.

** 5 of the 236 cottages are equipped with holding tanks and are therefore excluded from the calculation.

*** Only residences presumed not to be connected to community sewerage are included.

TABLE 7: CALCULATION PROCESS FOR THE DUMMY (BLUE) LAKE PHOSPHORUS BUDGET.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$3.735 \times 10^7 m^2$
2.	Lake Surface Area (Ao)	$2.003 \times 10^6 m^2$
3.	Surface Area of Other Lakes in A (Ao_1)	$1.939 \times 10^6 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$3.341 \times 10^7 m^2$
5.	Lake Volume (V)	$8.996 \times 10^6 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	4.49 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$1.191 \times 10^6 m^3/yr$
10.	Flushing Rate ($p = Q/V$)	0.132 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.595 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 + qs$)	0.957
13.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	8.212×10^7 mg/yr
15.	P Export Coefficient (E)	$23.3 mg/m^2/yr$
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	7.785×10^8mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	N/A
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	8.606×10^8mg/yr
18.	P Contribution per Capita Year (S)	8.0×10^5mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	2 units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	0.70 capita years
24.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	2.07×10^5mg/yr
25.	Number of Cottages (N_C)	1 unit
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	0 units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}'' = P_C \cdot N_C + P_D \cdot N_D$)	0.63 capita years
30.	P Contribution from Occupants ($J_A'' = S \cdot N_{CY}'' [1-R_S]$)	1.865×10^5 mg/yr
31.	Total P from Artificial Sources ($J_A = J_A' + J_A''$)	3.93×10^5mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	8.610×10^8mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.031 mg/L

TABLE 8: CALCULATION PROCESS FOR THE STEWART LAKE PHOSPHORUS BUDGET.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$4.573 \times 10^7 m^2$
2.	Lake Surface Area (Ao)	$2.616 \times 10^6 m^2$
3.	Surface Area of Other Lakes in A (Ao_1)	$1.180 \times 10^6 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$4.193 \times 10^7 m^2$
5.	Lake Volume (V)	$7.962 \times 10^6 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	3.04 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$1.645 \times 10^6 m^3$/yr
10.	Flushing Rate ($p = Q/V$)	0.207 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.629 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 + qs$)	0.955
13.	P Loading Rate for Precipitation (L_{Pr})	41 mg/m^2/yr
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	1.073×10^8 mg/yr
15.	P Export Coefficient (E)	23.3 mg/m^2/yr
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	9.770×10^8 mg/yr
16(a).	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	N/A
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	1.084×10^9 mg/yr
18.	P Contribution per Capita Year (S)	8.0×10^5 mg/yr.
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	10 units
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	3.52 capita years
24.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	1.041×10^6 mg/yr
25.	Number of Cottages (N_C)	1 unit
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	2 units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}" = P_C \cdot N_C + P_D \cdot N_D$)	9.23 capita years
30.	P Contribution from Occupants ($J_A" = S \cdot N_{CY}" [1-R_S]$)	7.384×10^6 mg/yr
31.	Total P from Artificial Sources ($J_A = J_A' + J_A"$)	8.425×10^6 mg/yr
32.	Total P Supply ($J_T = J_N + J_A$)	1.092×10^9 mg/yr
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.030 mg/L

TABLE 9: CALCULATION PROCESS FOR THE WOLF LAKE PHOSPHORUS BUDGET.

STEP	PARAMETER	QUANTITATION
1.	Gross Drainage Basin (A)	$5.678 \times 10^7 m^2$
2.	Lake Surface Area (Ao)	$2.98 \times 10^6 m^2$
3.	Surface Area of Other Lakes in A (Ao_1)	$2.26 \times 10^6 m^2$
4.	Drainage Basin ($Ad = A-[Ao+Ao_1]$)	$5.154 \times 10^7 m^2$
5.	Lake Volume (V)	$8.990 \times 10^6 m^3$
6.	Lake Mean Depth ($Z = V/Ao$)	3.02 m
7.	Net Annual Runoff (r)	0.051 m/yr
8.	Net Annual Evaporation (E_V)	-0.130 m/yr
9.	Outflow $Q = [Ad \cdot r]+E_V \cdot [Ao+Ao_1]$	$1.947 \times 10^6 m^3/yr$
10.	Flushing Rate ($p = Q/V$)	0.217 times/yr
11.	Areal Water Load ($qs = Q/Ao$)	0.653 m/yr
12.	Retention Coefficient ($R = 13.2/13.2 + qs$)	0.953
13.	P Loading Rate for Precipitation (L_{Pr})	$41 mg/m^2/yr$
14.	P Contribution from Precipitation ($J_{Pr} = L_{Pr} \cdot Ao$)	$1.222 \times 10^8 mg/yr$
15.	P Export Coefficient (E)	$23.3 mg/m^2/yr$
16.	P Contribution from Drainage Basin ($J_D = E \cdot Ad$)	$1.201 \times 10^9 mg/yr$
16(a).	P Contribution from Sediments During Anoxia ($J_S = L_S \cdot Ao \cdot days$)	1.132×10^9 mg/yr
17.	Total P from Natural Sources ($J_N = J_{Pr} + J_D + J_S$)	$2.455 \times 10^9 mg/yr$
18.	P Contribution per Capita Year (S)	$8.0 \times 10^5 mg/yr.$
19.	Sewage Treatment Retention Coefficient (R_S)	0.63
20.	Total Campground Site Units (U)	1 unit
21.	Mean Persons per Unit (P)	1.51 persons/unit
22.	Mean Season Length (SL)	85 days
23.	Campground Capita Years ($N_{CY}' = [U \cdot P \cdot SL]/365$)	0.35 capita years
24.	P Contribution from Campground ($J_A' = S \cdot N_{CY}' [1-R_S]$)	$1.04 \times 10^5 mg/yr$
25.	Number of Cottages (N_C)	0 units
26.	Capita Years per Cottage (P_C)	0.63 capita years
27.	Number of Residences (N_D)	3 units
28.	Capita Years per Residence (P_D)	4.3 capita years
29.	Total Occupant Capita Years ($N_{CY}" = P_C \cdot N_C + P_D \cdot N_D$)	12.9 capita years
30.	P Contribution from Occupants ($J_A" = S \cdot N_{CY}" [1-R_S]$)	$3.818 \times 10^6 mg/yr$
31.	Total P from Artificial Sources ($J_A = J_A' + J_A"$)	$3.922 \times 10^6 mg/yr$
32.	Total P Supply ($J_T = J_N + J_A$)	$2.459 \times 10^9 mg/yr$
33.	Predicted Spring Total P Concentration ($P = [J_T(1-R)]/Q$)	0.059 mg/L

Mean chlorophyll a concentrations were examined as a theoretical means of assessment of the validity of the phosphorus budgets (Table 10). Chlorophyll a production, when compared to the TSI-P and TSI-SD indices, appeared depressed but not significantly inhibited on Otter Lake . Therefore, it was concluded that chlorophyll a concentrations were suitable for theoretically evaluating the phosphorus budget of Otter Lakes. However, chlorophyll a concentrations were deemed unsuitable for evaluation of the phosphorus budgets of Little Jackfish, Sandy, Dummy, Stewart and Wolf lakes. This was because of significant chlorophyll a inhibition on each of these lakes (Table 10).

The phosphorus budget of Otter Lake was evaluated on a theoretical basis (Table 11) by substitution of observed chlorophyll a concentrations in the formulae of Dillon and Rigler (1974) and Riley and Prepas (1985), (equations 1(b) and 2(b), respectively). The results indicated that the observed chlorophyll a production in Otter Lake theoretically did require a significantly different concentration of total phosphorus than had been predicted by the phosphorus budget. This implied that the Otter Lake phosphorus budget (Table 4) was not valid and should be used for predictive purposes.

Table 10: CARLSON'S (1977) INDICES AS A TEST FOR THE VALIDITY OF USING THEORETICAL MEANS TO EVALUATE THE PHOSPHORUS BUDGETS

LAKE	TSI-P[1]	TSI-SD[2]	TSI-(chl)[3]	$\overline{TSI}$	RANGE DIFFERENCE /$\overline{TSI}$	Validity[4]
Otter	71.0	70.1	59.6	66.9	0.157	Valid
Little Jackfish	75.6	64.5	46.4	62.2	0.469	Not valid
Sandy	54.3	51.6	35.5	47.1	0.399	Not valid
Dummy (Blue)	53.6	48.9	31.5	44.7	0.494	Not valid
Stewart	54.6	50.8	36.9	47.4	0.373	Not valid
Wolf	65.7	62.0	42.7	56.8	0.405	Not valid

1 Per equation 5
2 Per equation 3
3 Per equation 4
4 Deemed valid where range difference /$\overline{TSI}$ <0.2

Table 11: VALIDATION OF PHOSPHORUS BUDGETS BY THEORETICAL CALCULATIONS

LAKE	CALCULATED [P] ±5%*	CALCULATED [P] ±17%	ACCEPTABLE RANGE OF [P]	PREDICTED [P]***	RANGE OF PREDICTED [P]	Validity
Otter	0.047	0.037	0.049-0.031	0.107	0.131-0.081	Not Valid
Little Jackfish	procedure not valid per Table 10					
Sandy	procedure not valid per Table 10					
Dummy (Blue)	procedure not valid per Table 10					
Stewart	procedure not valid per Table 10					
Wolf	procedure not valid per Table 10					

* Per equation 1(b); converted to mg/L
** Per equation 2(b); converted to mg/L
*** Per Tables 4-9 inclusive.

The inability to theoretically evaluate the phosphorus budgets by means of the 1986 data (Table 11) represented a dramatic change from 1985 (Beck, 1987). Since 1986 TSI-P and TSI-SD (Table 10) remained virtually unchanged from 1985 values, the inference was that factors other then nutrient availability and water clarity had inhibited chlorophyll a production. Two other such factors include light intensity (solar radiation) and physical room to grow (Reimer, 1984). Given that 1986 chlorophyll a production appeared inhibited as compared to 1985, physical room to grow seemed not to be a constraining factor. This, by default, implicated a change in meteorological conditions.

The phosphorus budgets of all six lakes were also evaluated (Table 12) by comparison to observed mean fall and winter total phosphorus concentrations. The observed concentrations for three lakes fell outside of the acceptable range for predicted spring total phosphorus concentrations. This meant that the phosphorus budgets developed for Otter, Little Jackfish and Sandy lakes (Tables 4, 5, and 6, respectively) were not valid and should not be used for predictive purposes. The observed concentrations for three lakes fell within the acceptable range for predicted spring total phosphorus concentrations. This meant that the phosphorus budgets calculated for Dummy, Stewart and Wolf lakes (Tables 7, 8 and 9, respectively) were valid and could be used for predictive purposes.

Table 12: VALIDATION OF PHOSPHORUS BUDGETS BY COMPARISON TO OBSERVED 1986-87 FALL & WINTER VALUES.

LAKE	PREDICTED* P (mg/L)	ACCEPTABLE RANGE (mg/L)	FALL & WINTER OBSERVED (mg/L)	MODEL VALIDITY
Otter	0.107	0.131-0.081	0.179	Not valid
Little Jackfish	0.016	0.019-0.013	0.201	Not valid
Sandy	0.015	0.018-0.012	0.030	Not valid
Dummy	0.031	0.037-0.025	0.034	Valid
Stewart	0.030	0.036-0.025	0.028	Valid
Wolf	0.059	0.071-0.047	0.062	Valid

* Per tables 4 to 9, inclusive.

3.3 Trophic Status

Two of the key criteria upon which the study recommendations were founded included aesthetic considerations and the maintenance of environmental quality. Both criteria are difficult to evaluate. Therefore, it was presumed that current conditions, though possibly not ideal, were at least minimally acceptable. This meant that the trophic status had to be determined and the stability of each lakes' condition had to be assessed.

Means of Carlson's (1977) indices (Table 10) were plotted in order to evaluate the trophic status of each lake (Figure 3). Vollenweider's (1975) plot (Figure 4) was used to assess the stability of the trophic states for those lakes where valid phosphorus budgets had been developed (Table 13).

Otter Lake and Little Jackfish Lake again fell within the upper eutrophic range (Figure 3). This meant that these lakes were extremely productive and would experience major blooms of blue-green algae (Cyanophytes) virtually every year. Mid-winter and possibly even mid-summer oxygen depletion accompanied by fish kills are expected to occur frequently. Generally, the water quality of highly eutrophic lakes is not considered suitable for body contact recreation. The stability of environmental quality in both Otter and Little Jackfish lakes again could not be assessed because valid phosphorus budgets were not developed for either lake.

Wolf Lake fell into the moderately eutrophic range (Figure 3). This meant that the lake was very productive and will also frequently experience major blooms of Cyanophytes. Mid-winter oxygen

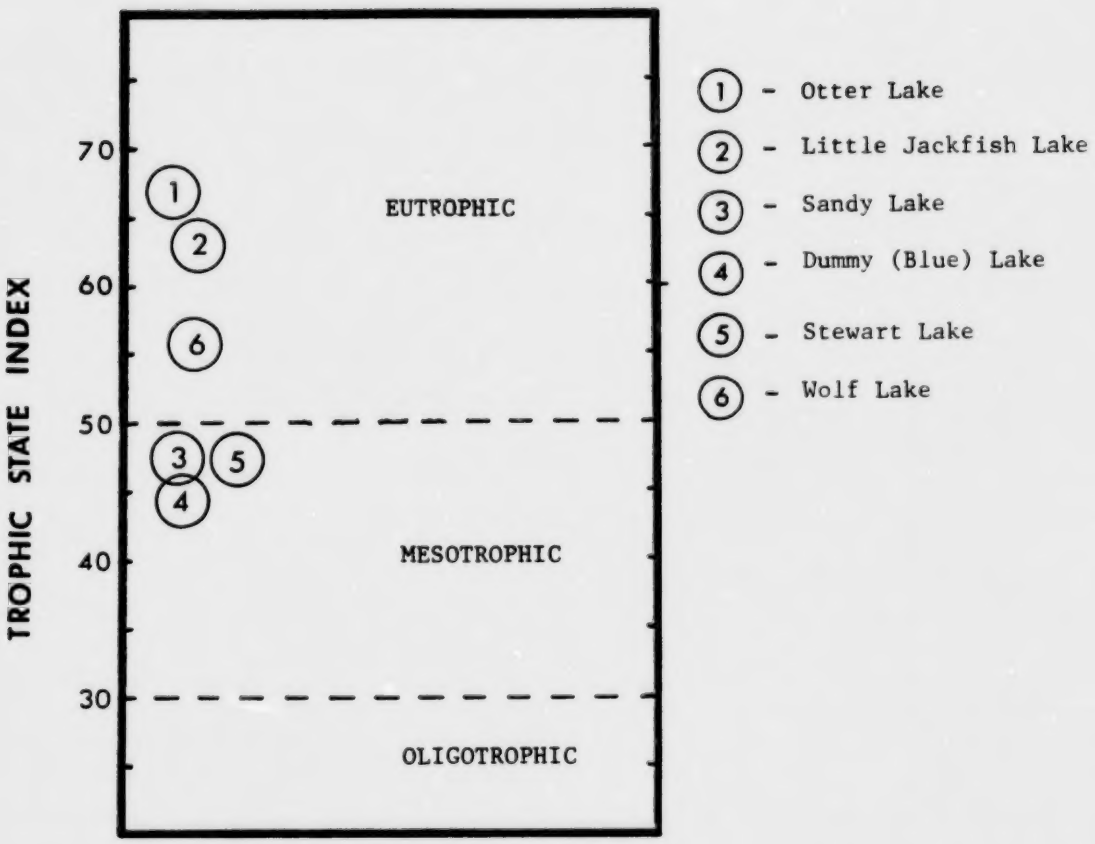

Figure 3: Carlson's (1977) mean trophic state indices (TSI) for the South Riding Mountain Planning District Lake.

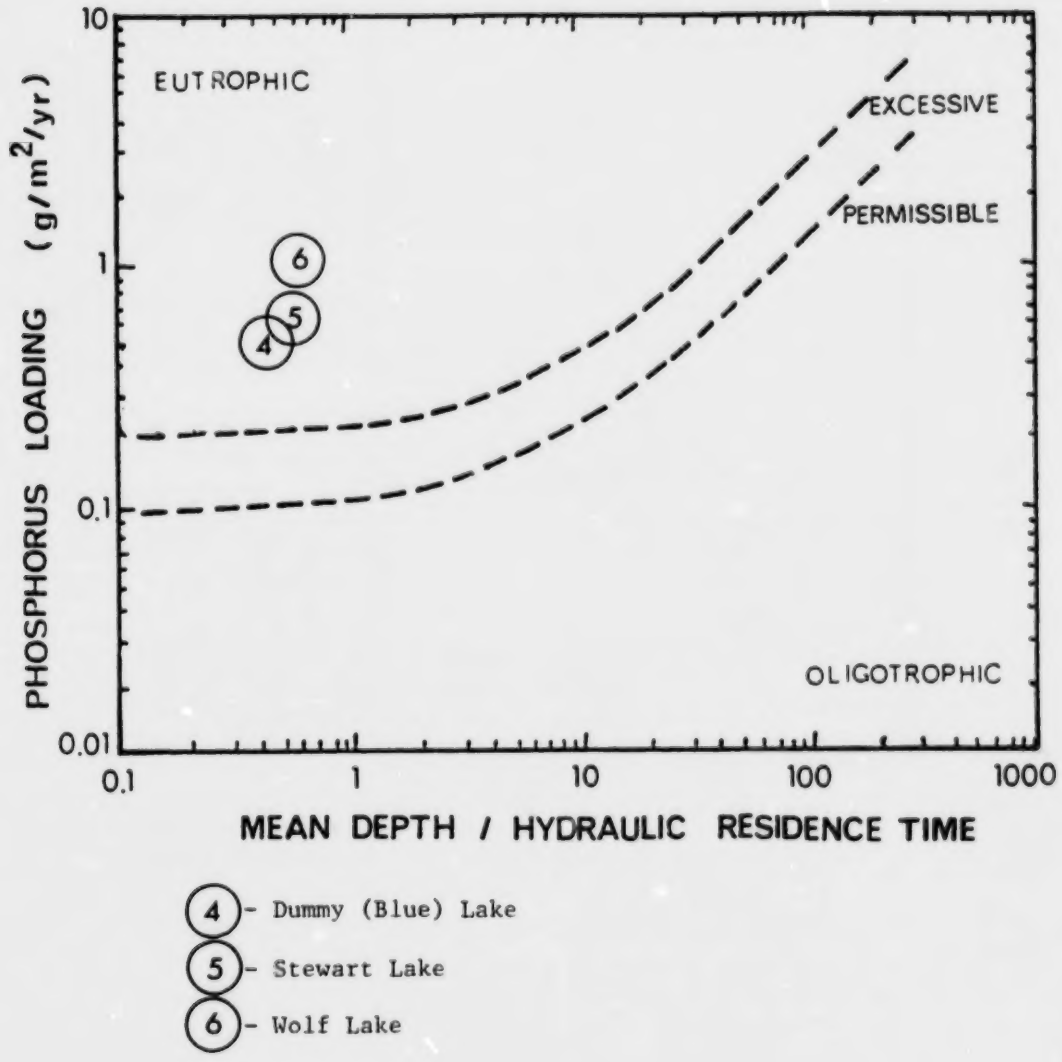

Figure 4: Application of Vollenweider's (1975) trophic state scale to lakes of the South Riding Mountain Planning District.

TABLE 13: PHOSPHORUS LOADING RATES AND (MEAN DEPTH/HYDRAULIC RESIDENCE TIME) FOR LAKES WITH VALID PHOSPHORUS BUDGETS

Lake	Phosphorus Loading ($g/M^2/yr$)	Mean Depth / Hydraulic Residence Time *
Dummy (Blue) Lake	0.43	0.595
Stewart Lake	0.42	0.629
Wolf Lake	0.83	0.653

* This value is equivalent to qs from Tables 7, 8, and 9 respectively

depletions accompanied by fish kills would not be uncommon. Generally, the water quality of moderately eutrophic lakes is considered suitable for recreational purposes except during major Cyanophyte blooms. Vollenweider's (1975) plot (Figure 4) indicated that Wolf Lake was subject to excessive rates of background phosphorus loadings. This meant that water quality conditions were expected to rapidly deteriorate over time unless ameliorative actions were taken.

Sandy Lake, Dummy Lake and Stewart Lake were classified as mesotrophic (Figure 3). This apparent decline in mean TSI values from 1985 (Beck, 1987) suggested an unrealistic improvement in water quality that was not supported by field observations. Rather, as suggested by Beck (1987), the extensive macrophyte growths in deeper areas (2-3 meters) and the dense colonies of filamentous algae in shallower (<2 metres) areas may cause stripping of nutrients from the water column and sediments at an accelerated rate, thereby reducing the potential for Cyanophyte production and hence, artificially suppressing mean TSI values. Accordingly, the water quality of Sandy Lake again might better be assessed as moderately eutrophic. In a similar manner Dummy Lake and Stewart Lake might be better classified again as borderline between the eutrophic and mesotrophic states.

The stability of environmental conditions in Sandy Lake again could not be evaluated since a valid phosphorus budget was not developed for this waterbody. Dummy Lake and Stewart Lake were quite productive and might experience major blooms of Cyanophytes. However, the duration and magnitude of Cyanophyte blooms was expected to be

considerably less than those which developed on eutrophic waterbodies. Mid-winter oxygen depletions accompanied by fish kills might occur infrequently. Generally, the water quality of such borderline lakes is considered suitable for recreational purposes. Vollenweider's (1975) plot (Figure 4) indicated that both Dummy Lake and Stewart Lake were subject to excessive rates of phosphorus loadings. Therefore, the water quality of each was expected to continue to slowly deteriorate unless ameliorative action was taken.

3.4 Cottage Equivalent Capacities

Cottage equivalent capacities,* as previously discussed, are calculated according to procedures modified from Hough, Stansbury and Michalski Limited (1980). Capacities were calculated only for the three lakes for which valid phosphorus budgets had been developed (Dummy, Stewart and Wolf Lakes).

It was estimated that Dummy Lake has the ability to accommodate a maximum of 111 cottage equivalents without inducing detectable water quality degradation (Table 14). There is currently 1 cottage located at the lake (W. Dmyterko, pers. com.) and present alternate usage has been estimated at the equivalent of 2 campsites (Table 7). Therefore a further 109 cottage equivalents may be accomodated. It is recommended that future developments not exceed a

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* The term "cottage equivalent" implies that alternate uses can be readily accommodated by application of appropriate conversion factors. For example, when estimating phosphorus loadings, one cottage is equivalent to either 0.147 permanent residences, or to 4.5 campsites.

lake total of 109 additional cottage equivalents. Furthermore, because of the very excessive background rate of nutrient loadings (Figure 4), it is also recommended that potential developers and prospective recreational investors be advised that occasional water quality problems can be anticipated.

Stewart Lake has the estimated ability to accommodate a maximum of 147 cottage equivalents without inducing a detectable deterioration of lake water quality (Table 25). Present alternate usage has been estimated at the equivalent of 10 campsites (Table 8). Two residences and one cottage unit are currently located at the site (W. Dmyterko, pers. com.). Therefore, a further 131 cottage equivalents may be accommodated. It is recommended that future developments not exceed a lake total of 131 additional cottage equivalent units. Furthermore, because of the excessive background rate of nutrient loadings (Figure 4) it is also recommended that potential developers and prospective recreational investors be advised that occasional water quality problems can be anticipated.

It was estimated that Wolf Lake could accomodate a total of 278 cottage equivalent units without a detectable environmental impact upon water quality (Table 16). However, the eutrophic state of the lake (Figure 3) and the excessive rate of phosphorus loadings suggest that severe water quality problems will occur annually. This implies that Wolf Lake is not suitable for recreational developments of a permanent nature. Rather, intensive day use facilities might be more appropriate for use during those occasional periods when water quality

TABLE 14: CALCULATION PROCESS FOR ESTIMATION OF DUMMY (BLUE) LAKE COTTAGE EQUIVALENT CAPACITY

STEP	PARAMETER	QUANTITATION
1.	P Contribution per capita (S)	8.0×10^5 mg/yr.
2.	Sewage Treatment Retention Coefficient (R_s)	0.63
3.	Capita Years per Cottage (P_C)	0.63 capita years
4.	Total P supply (J_T)	8.610×10^8 mg/yr.
5.	Number of Cottages (N_C)	1 unit
6.	Campground Capita Years (N_{CY}')	0.70 capita years
7.	Total Campground and Cottage Capita Years ($N_{CY}^2 = P_C \cdot N_C + N_{CY}'$)	1.33 capita years
8.	P Contributions from Cottages and Campgrounds ($J_{C1} = N_{CY}^2 \cdot S \cdot [1-R_s]$)	3.940×10^5 mg/yr
9.	Significance of Non -J_{C1} Contributions ($K = [J_T - J_{C1}]/J_T$)	0.9995
10.	Predicted P (P)	0.031 mg/L
11.	Predicted P minus J_{C1} Contributions ($P_1 = P \cdot K$)	0.031 mg/L
12.	Analytical Error Associated with P_1 (E_1)	0.003 mg/L
13.	Calculation Error Permitted ($E = [E_1/_4]$)	0.75 µg/L
14.	Outflow (Q)	1.191×10^6 m^3/yr.
15.	Retention Coefficient (R)	0.957
16.	Permissible Cottage and Campground Loading ($J_{CP} = E \cdot Q/[1-R]$)	2.077×10^7 mg/yr.
17.	Permissible Number of Cottage Equivalents ($N_{CE} = J_{CP}/[1-Rs] \cdot P_C \cdot S$)	111 units

TABLE 15: CALCULATION PROCESS FOR ESTIMATION OF STEWART LAKE COTTAGE EQUIVALENT CAPACITY

STEP	PARAMETER	QUANTITATION
1.	P Contribution per capita (S)	8.0×10^5 mg/yr.
2.	Sewage Treatment Retention Coefficient (R_s)	0.63
3.	Capita Years per Cottage (P_C)	0.63 capita year
4.	Total P supply (J_T)	1.092×10^9 mg/y
5.	Number of Cottages (N_C)	1 unit
6.	Campground Capita Years (N_{CY}')	3.52 capita year
7.	Total Campground and Cottage Capita Years ($N_{CY}^2 = P_C \cdot N_C + N_{CY}'$)	4.15 capita year
8.	P Contributions from Cottages and Campgrounds ($J_{C1} = N_{CY}^2 \cdot S \cdot [1-R_s]$)	1.228×10^6 mg/y
9.	Significance of Non -J_{C1} Contributions ($K = [J_T - J_{C1}]/J_T$)	0.999
10.	Predicted P (P)	0.030 mg/L
11.	Predicted P minus J_{C1} Contributions ($P_1 = P \cdot K$)	0.030 mg/L
12.	Analytical Error Associated with P_1 (E_1)	0.003 mg/L
13.	Calculation Error Permitted ($E = [E_1/4]$)	0.75 µg/L
14.	Outflow (Q)	1.645×10^6 m^3/yr
15.	Retention Coefficient (R)	0.955
16.	Permissible Cottage and Campground Loading ($J_{CP} = E \cdot Q/[1-R]$)	2.742×10^7 mg/y
17.	Permissible Number of Cottage Equivalents ($N_{CE} = J_{CP}/[1-Rs] \cdot P_C \cdot S$)	147 units

TABLE 16: CALCULATION PROCESS FOR ESTIMATION OF WOLF LAKE COTTAGE EQUIVALENT CAPACITY

STEP	PARAMETER	QUANTITATION
1.	P Contribution per capita (S)	8.0×10^5 mg/yr.
2.	Sewage Treatment Retention Coefficient (R_s)	0.63
3.	Capita Years per Cottage (P_C)	0.63 capita years
4.	Total P supply (J_T)	2.459×10^9 mg/yr.
5.	Number of Cottages (N_C)	0 unit
6.	Campground Capita Years (N_{CY}')	0.35 capita years
7.	Total Campground and Cottage Capita Years ($N_{CY}^2 = P_C \cdot N_C + N_{CY}'$)	0.35 capita years
8.	P Contributions from Cottages and Campgrounds ($J_{C1} = N_{CY}^2 \cdot S \cdot [1-R_s]$)	1.04×10^5 mg/yr
9.	Significance of Non -J_{C1} Contributions ($K = [J_T - J_{C1}]/J_T$)	1.00
10.	Predicted P (P)	0.059 mg/L
11.	Predicted P minus J_{C1} Contributions ($P_1 = P \cdot K$)	0.059 mg/L
12.	Analytical Error Associated with P_1 (E_1)	0.005 mg/L
13.	Calculation Error Permitted ($E = [E_1/4]$)	1.25 µg/L
14.	Outflow (Q)	1.947×10^6 m^3/yr.
15.	Retention Coefficient (R)	0.953
16.	Permissible Cottage and Campground Loading ($J_{CP} = E \cdot Q/[1-R]$)	5.178×10^7 mg/yr.
17.	Permissible Number of Cottage Equivalents ($N_{CE} = J_{CP}/[1-Rs] \cdot P_C \cdot S$)	278 units

might be acceptable. Therefore, it is recommended that recreational developments at Wolf Lake be restricted to day use facilities and that permanent developments not be permitted on the lake.

Despite the failure to develop valid phosphorus budgets for Otter, Little Jackfish and Sandy Lakes, generalizations about recreational developments may be drawn from the respective trophic conditions. Both Otter Lake and Little Jackfish Lake fell within the upper eutrophic range (Figure 3). This state is consistent with frequent extensive periods of poor water quality. Although substantial levels of recreational development are unlikely to induce rapid detectable water quality deterioration, the existing poor and volatile water quality conditions would probably quickly displease recreationers who may have invested substantial sums in permanent developments. Such persons are likely to vocalize their concerns and demand ameliorative action. Since ameliorative action for such lakes is typically prohibitively expensive and often ineffective, it may be prudent to avoid potential problems and discourage any further recreational developments of a permanent nature. Therefore, it is recommended that further recreational development of a permanent nature (e.g. cottages) not be permitted on Otter Lake and on Little Jackfish Lake.

The trophic status of Sandy Lake, as previously discussed, was partially masked by extensive growths of both macrophytes and filamentous algae. The inference was that Sandy Lake was eutrophic and subject to excessive rates of nutrient loadings. The implication was that additional nutrient loading, such as might be induced by

further recreational development, might "tip the balance" and again accelerate the advance of eutrophy. These considerations and the present advanced state of recreational development about the lake suggest that Sandy Lake has already been developed to a point near the potential maximum. Therefore, it is recommended that further recreational development not be permitted on Sandy Lake.

3.5 Boat Capacities*

Boat capacities are calculated in order to assess the potential for conflicts among various users. Such conflicts may be mechanical (e.g. collisions), physical interference which creates hazardous conditions (e.g. waterskiing and swimming), or psychological interference (e.g. still fishing and high speed boating) (Thomas, 1983). Boat capacities may also be used as an aid to guide development. They are of particular assistance when current boating practices are moderate to heavy but the potential for development has not been fully realized. Respective boat capacities reported by Beck (1987) have been partially reproduced for the sake of report self-sufficiency.

Current boating use of Otter Lake was estimated at 37% of capacity (Table 17). This suggested that there was no appreciable level of conflict between various water based recreational activities on the lake.

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* Within the context of this report, the term "boat" refers to all water crafts including motorboats, canoes, sailboats, sailboards, pedal boats, rafts, etc.

Current boating use of Little Jackfish Lake was estimated at 8% of capacity (Table 17). This light rate of use indicated that conflicts between various water based recreational activities should not occur on the lake at the present level of development.

It was estimated that up to 77 boats may operate safely on Sandy Lake at any one time (Table 17). Current boating use was moderately heavy and approximated 57% of capacity (Ibid). Again, significant conflicts between various water based recreational activities were considered unlikely under present use patterns.

It was estimated that current boating use of Dummy Lake approximated 5% of capacity (Table 17). This light rate of use indicated that conflicts between various water based recreational activities were unlikely to occur at the present level of development. However, it was previously estimated that Dummy Lake could accomodate further development up to 109 cottage equivalent units without detectably affecting water quality (Section 3.4). Assuming that the entire 109 unit capacity was devoted to cottages, the additional maximum instantaneous boat use would approximate 20 boats (Equation 6). This consumes the entire boat space which had been available and would permit no further development. Assuming that the entire available boat space (20 boats, Table 17) had been allocated to campsites/day use sites, only 49 campsites/day use sites (per Equation 6) could be accomodated. The ratio of permissible cottage equivalent units (i.e. 109 units) to permissible campsite/day use sites (i.e. 49 units) was 2.22. Therefore it is recommended that

TABLE 17: BOAT CAPACITIES FOR LAKES OF THE SOUTH RIDING MOUNTAIN PLANNING DISTRICT.

Lake	Lake Surface Area >1.5 m Depth (ha)	Maximum Instantaneous Boat Capacity (Boats)	Maximum Instantaneous Current Use (Boats)	Capacity - Current Use (Boats)	Current Use /Capacity (%)
Otter	499	95	35	60	37%
Little Jackfish	61	12	1	11	8%
Sandy	405	77	44	33	57%
Dummy	110	21	1	20	5%
Stewart	210	40	6	34	15%
Wolf	227	43	1	42	2%

the campsites/day use sites are factored at a rate of 2.22 when compared to cottages for the purpose of evaluating further development proposals.

Utilization of Stewart Lake was estimated at 15% of capacity (Table 17). Similar to Dummy Lake, conflicts between various water based recreational activities were unlikely to occur at the present level of development. It was previously estimated that Stewart Lake could accomodate a further 131 cottage equivalent units without inducing detectable water quality deterioration (Section 3.4). Assuming that the entire 131 unit capacity was devoted to cottages, the additional maximum instantaneous boat use would approximate 23 boats (Equation 6). Though somewhat crowded (73% of capacity), this is still within boating capacity limits for the lake. Had the entire available boat space (34 boats, Table 17) been allocated to campsites/day use sites, only 85 units (per Equation 6) could be accomodated. The ratio of cottage equivalent units (i.e. 131 units) to campsites/day use sites (i.e. 85 units) was 1.54. Therefore it is recommended that the campsites/day use sites are factored at a rate of 1.54 when compared to cottages for the purpose of evaluating future development proposals.

Wolf Lake has an estimated capability to accomodate a maximum of 43 boats (Table 17). Since only temporary campsites/day use sites should be permitted, the current boat capacity not utilized (i.e. 42 boats, Table 17) approximates 105 temporary campsite/day use site units. Therefore it is recommended that further recreational development at Wolf Lake be restricted to a maximum of 105 temporary campsites/day use sites.

4.0 CONCLUSIONS

The nature of the present study yielded a variety of conclusions about each of the lakes investigated. Given the singular interests of the majority of intended readers, the conclusions have been organized on an individual lake basis.

Otter Lake:

It was concluded that:

a) Otter Lake is a highly eutrophic waterbody;

b) the water quality is not considered suitable for many recreational purposes;

c) phosphorus is the limiting nutrient which controls algae and macrophyte growth in Otter Lake*;

d) existing poor water quality conditions render Otter Lake unsuitable for further recreational development of a permanent nature;

e) significant conflicts between various water based recreational activities are unlikely at current rates of utiiization of Otter Lake.

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* This conclusion represents a revision from Beck (1987)

Little Jackfish Lake:

It was concluded that:

a) Little Jackfish Lake is a highly eutrophic waterbody;

b) the water quality is not considered suitable for many recreational purposes;

c) nitrogen is the limiting nutrient which controls algae and macrophyte growth in Little Jackfish Lake;

d) existing water quality conditions render Little Jackfish Lake unsuitable for further recreational development of a permanent nature;

e) significant conflicts between various water based recreational activities are unlikely at present rates of utilization of Little Jackfish Lake.

Sandy Lake:

It was concluded that:

a) Sandy Lake is an eutrophic waterbody;

b) the water quality is generally suitable for recreational purposes except during major blue-green algae (Cyanophyte) blooms;

c) phosphorus is the limiting nutrient which controls algae and macrophyte growth in Sandy Lake;

d) recreational development about Sandy Lake approaches the maximum potential;

e) further recreational development should not be permitted on Sandy Lake;

f) significant conflicts between various water based recreational activities are unlikely at the present moderately heavy rates of utilization of Sandy Lake.

Dummy (Blue) Lake:

It was concluded that:

a) Dummy Lake is a borderline eutrophic waterbody;

b) the water quality generally is suitable for recreational purposes except during particularly severe blue-green algae (Cyanophyte) blooms;

c) water quality conditions will continue to deteriorate over time unless ameliorative action is taken;

d) phosphorus is the limiting nutrient which controls algae and macrophyte growth in Dummy Lake;

e) a valid phosphorus budget was developed for predictive purposes;

f) the rate of background phosphorus loading was very excessive;

g) Dummy Lake can accomodate an estimated maximum of 111 cottage equivalent units of development without inducing detectable water quality deterioration;

h) the present degree of development at Dummy Lake approximates 2 cottage equivalent units;

i) an estimated maximum of 109 additional cottage equivalent units may be accomodated at Dummy Lake without inducing detectable water quality deterioration;

j) cottage equivalent units for Dummy Lake may be calculated at the rate of 1 cottage = 0.147 residences = 2.22 campsites/day use sites;

k) current boating use of Dummy Lake is light and well within capacity for the lake;

l) significant conflicts between various water based recreational activities are unlikely assuming that the development capacity of the lake is not exceeded.

Stewart Lake:

It was concluded that:

a) Stewart Lake is a borderline eutrophic waterbody;

b) the water quality generally is suitable for recreational purposes except during particularly severe blue-green algae (Cyanophyte) blooms;

c) water quality conditions will continue to deteriorate over time unless ameliorative action is taken;

d) phosphorus is the limiting nutrient which controls algae and macrophyte growth in Stewart Lake;

e) a valid phosphorus budget was developed for predictive purposes;

f) the rate of background phosphorus loading was very excessive;

g) Stewart Lake can accomodate an estimated maximum of 147 cottage equivalent units of development without inducing detectable water quality deterioration;

h) the present degree of development at Stewart Lake approximates 16 cottage equivalent units;

i) an estimated maximum of 131 additional cottage equivalent units may be accomodated at Stewart Lake without inducing detectable water quality deterioration;

j) cottage equivalent units for Stewart Lake may be calculated at the rate of 1 cottage - 0.147 residences = 1.54 campsites/day use sites;

k) current boating use of Stewart Lake is light and well within capacity for the lake;

l) significant conflicts between various water based recreational activities are unlikely assuming that the development capacity of the lake is not exceeded.

Wolf Lake:

It was concluded that:

a) Wolf Lake is a moderately eutrophic waterbody;

b) the water quality generally is suitable for recreational purposes except during severe blue-green algae (Cyanophyte) blooms;

c) water quality conditions will continue to rapidly deteriorate over time unless ameliorative action is taken;

d) phosphorus is the limiting nutrient which controls algae and macrophyte growth in Wolf Lake;

e) a valid phosphorus budget was developed for predictive purposes;

f) the rate of background phosphorus loading was very excessive;

g) the moderately eutrophic state of Wolf Lake coupled with the very excessive background rate of phosphorus loadings will induce severe water quality problems annually;

h) Wolf Lake is not suitable for recreational development of a permanent nature;

i) Wolf Lake is suitable for non permanent recreational developments such as temporary campsites and day use sites during those occasional periods when water quality might be acceptable;

j) Wolf Lake could accomodate an estimated maximum of 278 cottage equivalent units without inducing detectable water quality deterioration;

k) cottage equivalent units for Wolf Lake may be calculated at the rate of 1 cottage = 0.147 residences = 2.65 campsites/day use sites;

l) current boating use of Wolf Lake is light and well within capacity for the lake;

m) significant conflicts between various water based recreational activities are unlikely assuming that the development capacity of the lake is not exceeded.

5.0 RECOMMENDATIONS

Given the singular interests of the majority of intended readers, the recommendations have been organized on an individual lake basis.

Otter Lake:

It is recommended that further recreational development of a permanent nature (e.g. cottages) not be permitted on Otter Lake.

Little Jackfish Lake:

It is recommended that further recreational development of a permanent nature (e.g. cottages) not be permitted on Little Jackfish Lake.

Sandy Lake:

It is recommended that further recreational development not be permitted on Sandy Lake.

Dummy (Blue) Lake:

It is recommended that:

a) future development at Dummy Lake not exceed a lake total of 109 additional cottage equivalent units;

b) cottage equivalent units for Dummy Lake be calculated at the rate of 1 cottage = 0.147 residences = 2.22 campsites/day use sites;

c) potential developers and prospective recreational investors be advised that occasional water quality problems can be anticipated.

Stewart Lake:

It is recommended that:

a) future development at Stewart Lake not exceed a lake total of 131 additional cottage equivalent units;

b) cottage equivalent units for Stewart Lake be calculated at the rate of 1 cottage = 0.147 residences = 1.54 campsites/day use sites;

c) potential developers and prospective recreational investors be advised that occasional water quality problems can be anticipated.

Wolf Lake:

It is recommended that:

a) further recreational development of a permanent nature (e.g. cottages) not be permitted on Wolf Lake;

b) further recreational development of a temporary nature be restricted to a lake maximum of 105 campsites/day use sites.

6.0 ACKNOWLEDGEMENTS

Credit for the impetus resulting in the present study properly belongs to the South Riding Mountain Planning District Board. The foresight, concern and attention of the Board Members is gratefully acknowledged. Mr. Wally Dmyterko, Secretary-Treasurer to the Board, played several key roles in the project. His detailed knowledge of the study area, command of local development facts and supervision of field staff were instrumental to the success of the project. Particular appreciation must also be expressed to Mr. Bob Philipation and Mr. Michael Popp, whose labors were essential to project completion. Bob and Michael conducted the field work in a diligent and conscientious manner and their efforts are greatly appreciated. The contour figures of three lakes that were provided by Mr. Brian Yake (Western Region Fisheries Branch) are also acknowledged. We are indebted to staff of the W. M. Ward Technical Services Laboratory for sample analysis. Term funding for summer staff was provided by the "Career Start "86" program. Summer field operational expenses were covered by the South Riding Mountain Planning District.

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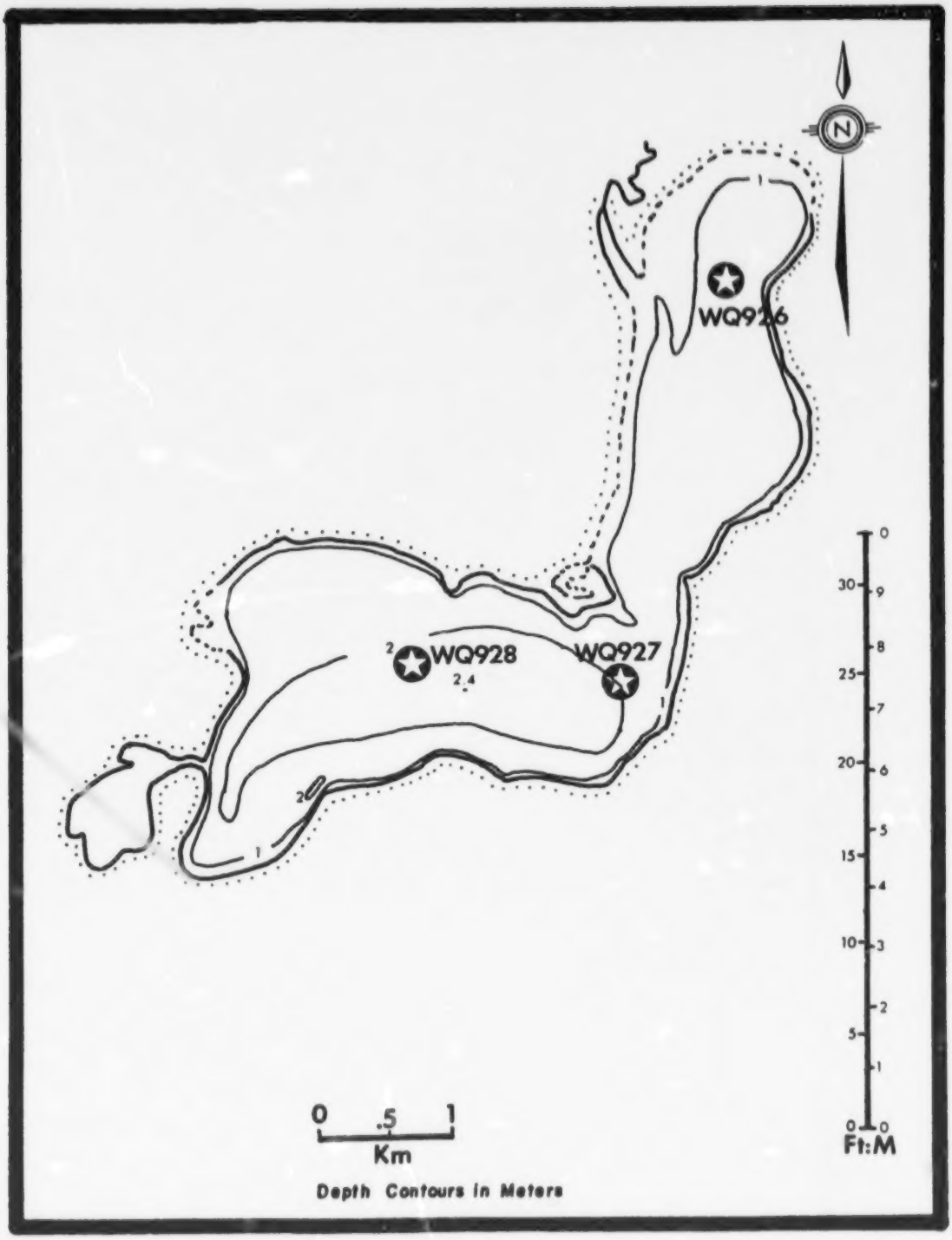
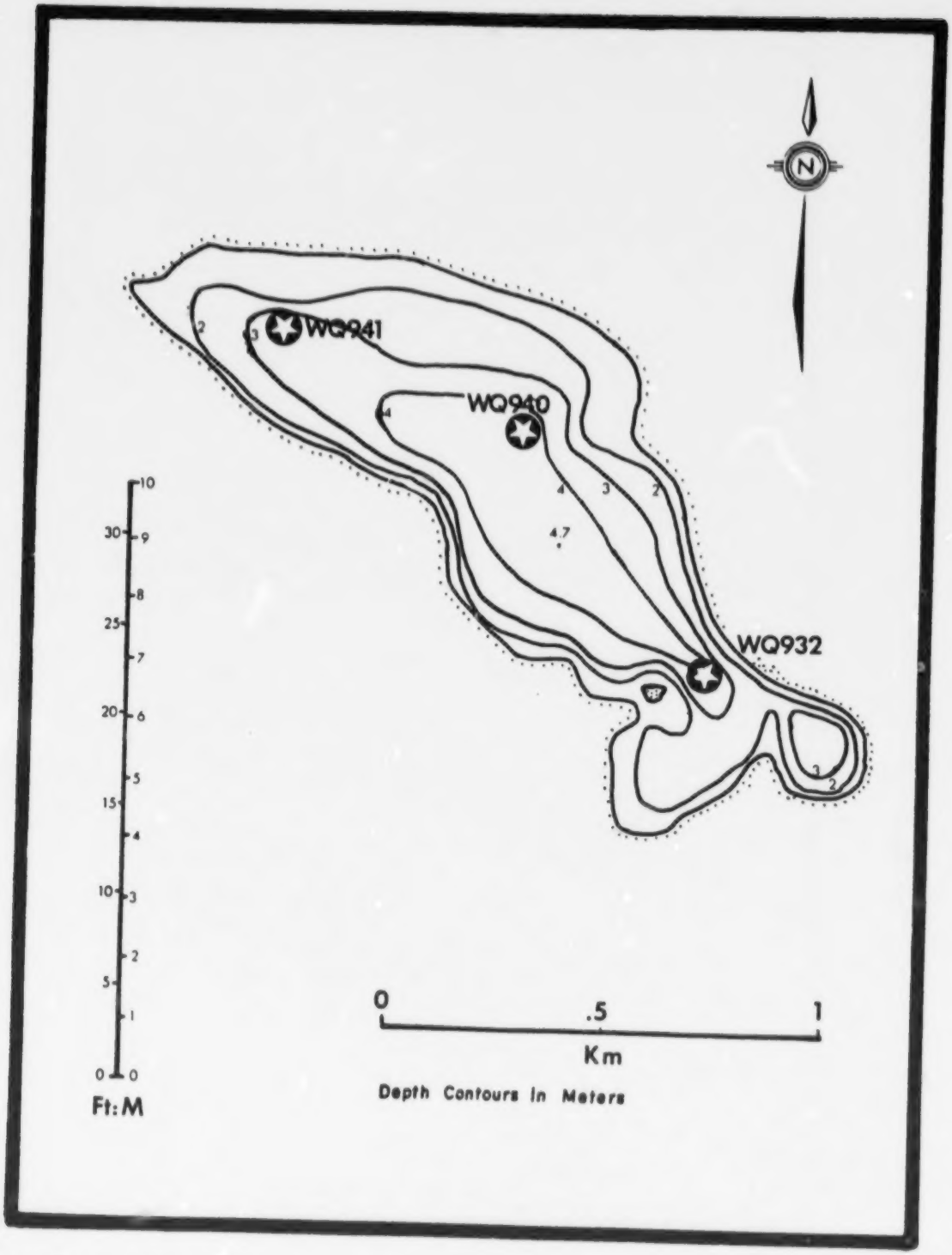
Appendix I(a)



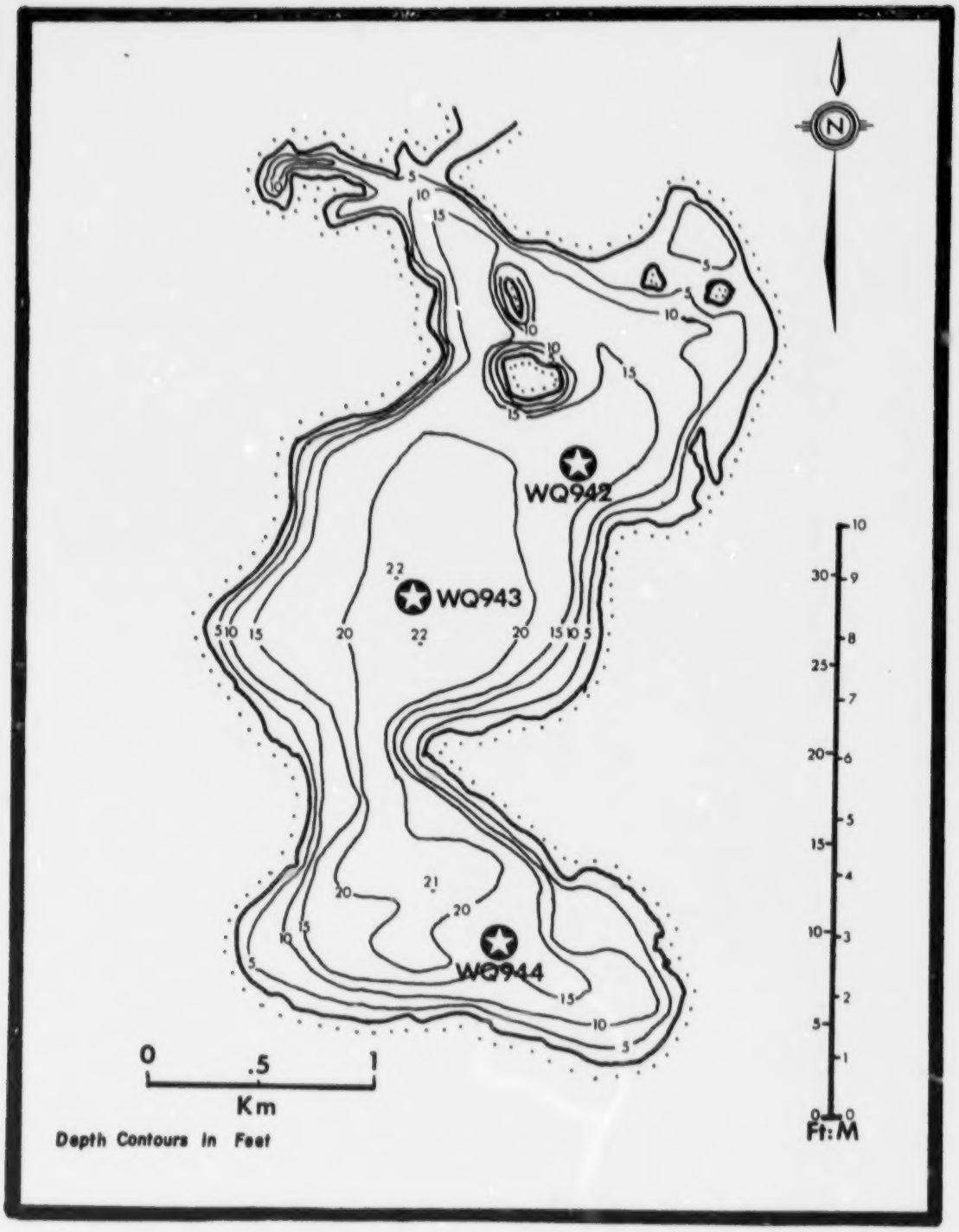
Otter Lake contours (m) and sampling stations.

Appendix I(b)



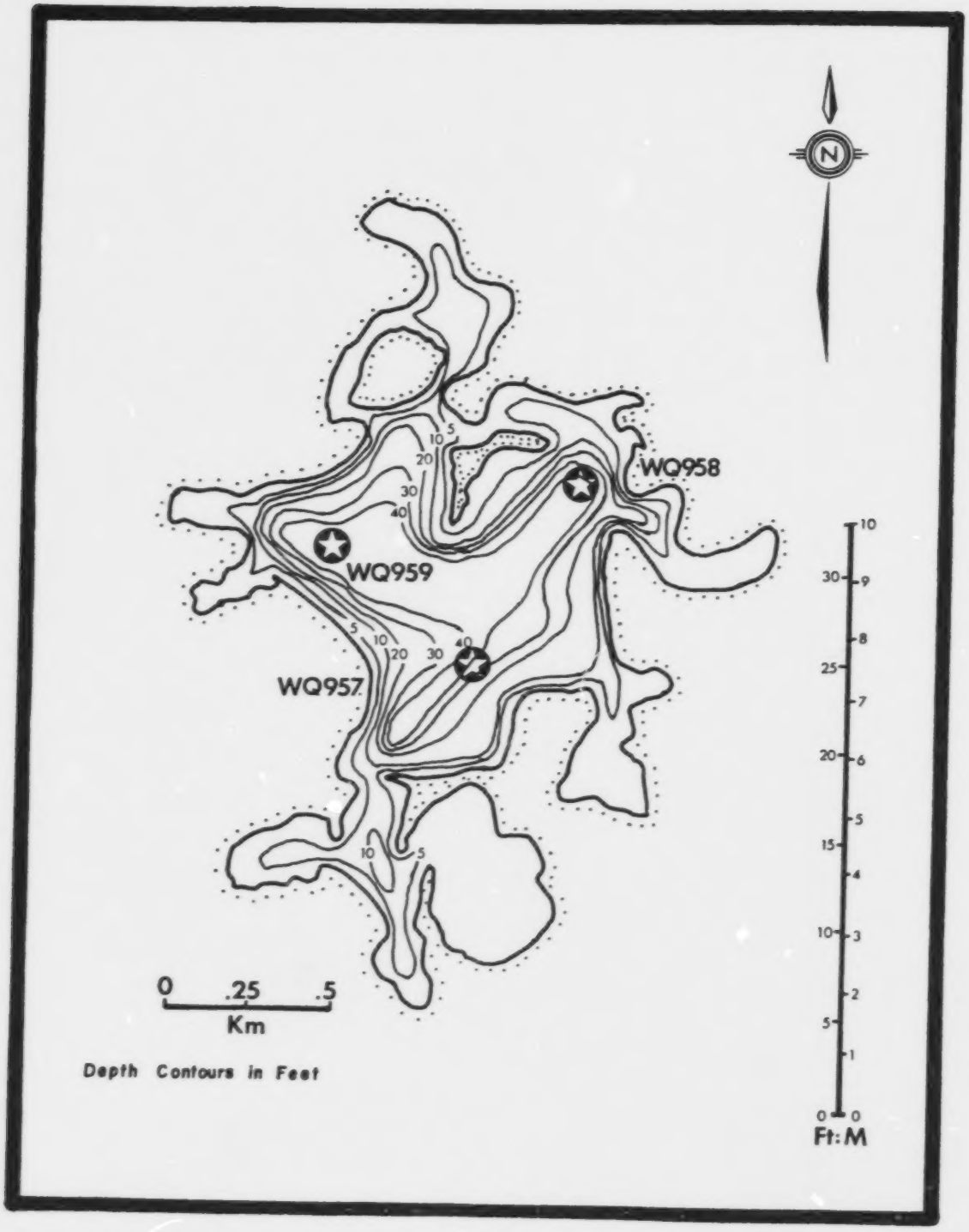
Little Jackfish Lake contours (m) and sampling stations.

Appendix I(c)



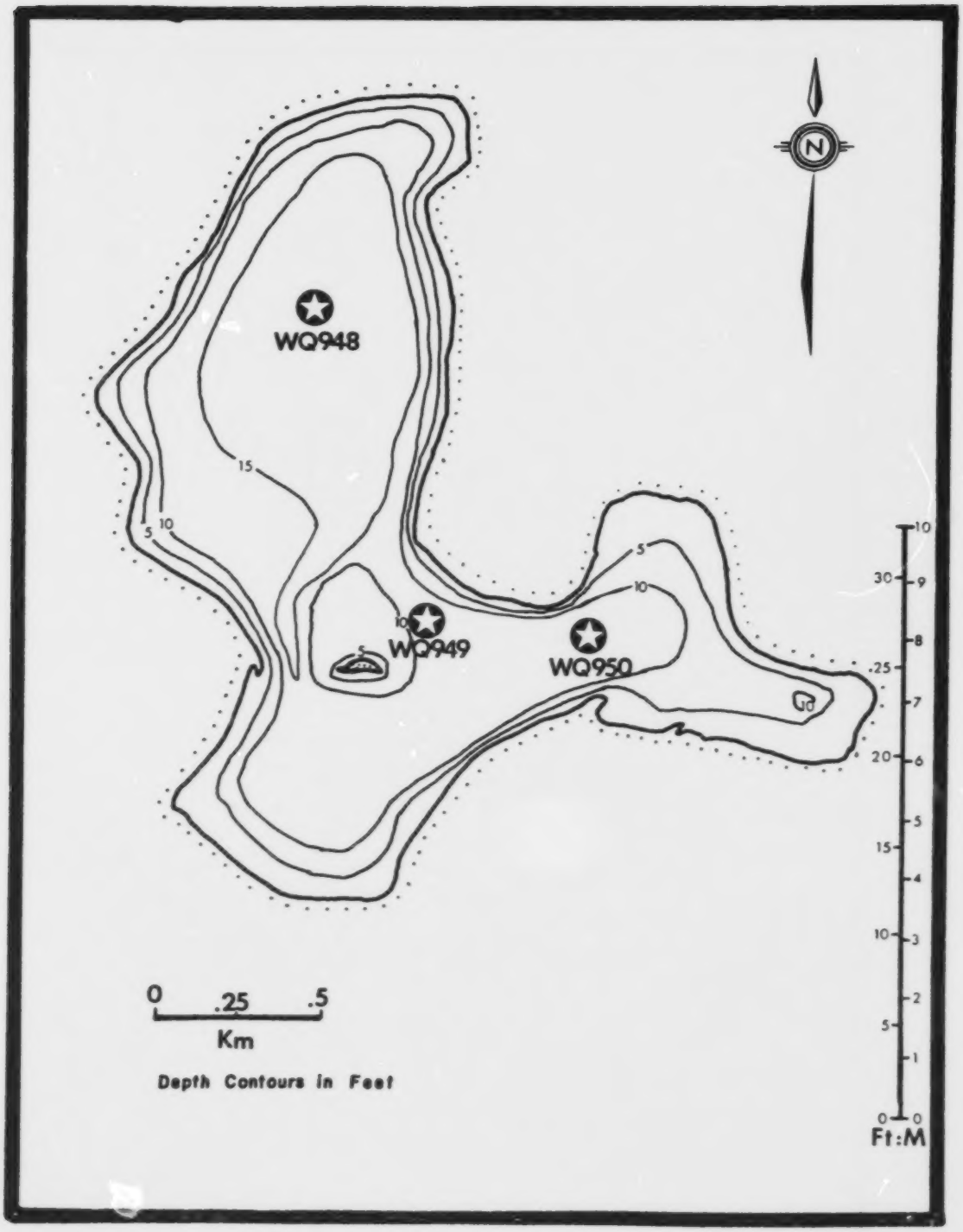
Sandy Lake contours (ft.) and sampling stations.

Appendix I(d)



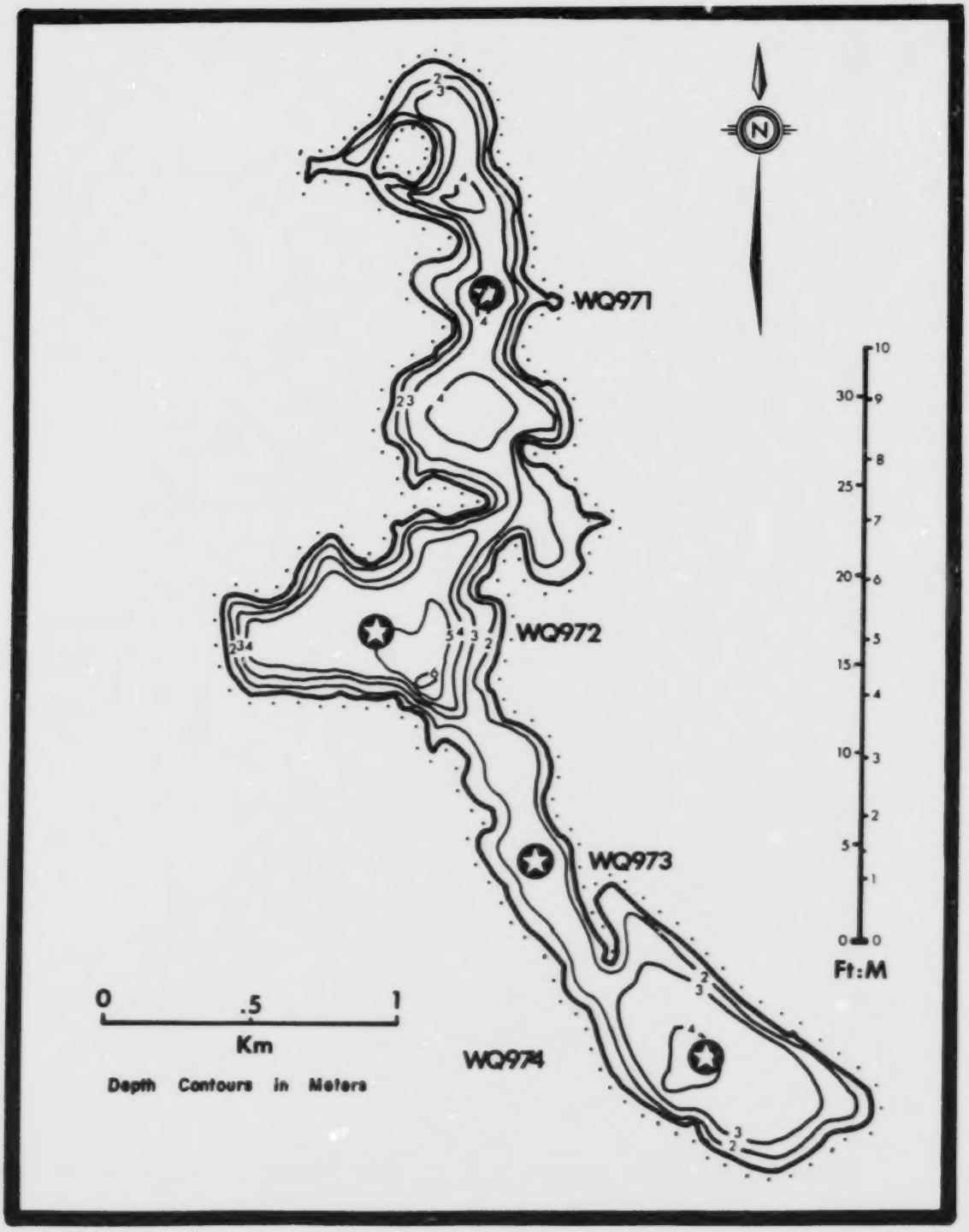
Dummy (Blue) Lake contours (ft.) and sampling stations.

Appendix I(e)



Stewart Lake contours (ft.) and sampling stations.

Appendix 1(f)



Wolf Lake contours (m) and sampling stations.

Appendix II(a)

MANITOBA

Inter-Departmental Memo

Date January 18, 1980

To Mr. Grant McLeod
Director of Environmental Control Branch
Environmental Management Division
139 Tuxedo Avenue

From N. Mudry, P.Eng.,
Director of Planning
Water Resources Branch
1577 Dublin Avenue

File: 4.3.2

Telephone

Subject Information on Selected Manitoba Lakes

Further to your memoranda of June 13 and July 24, 1979 requesting information on a number of Manitoba lakes please find the following:

1. An estimate of annual runoff, annual net evaporation over the lake, gross basin drainage area and lake surface area has been prepared for each of the lakes and is summarized in Table 1.

2. Recorded water level information for Thomas, Sharpe and Dromore Lakes.

3. Copies of the maps showing the delineation of the drainage area contributing to each lake will be forwarded when drafting has been completed.

If any questions should arise, please contact Mr. D. Donachuk at 786-9396.

N. Mudry

Attachments

TABLE 1

METEOROLOGICAL AND SURFACE AREA INFORMATION

	SUBJECT	GROSS DRAINAGE AREA IN SQ. KM.	LAKE SURFACE AREA IN SQ. KM	ANNUAL NET EVAPORATION OVER LAKE IN MILLIMETERS					ANNUAL RUNOFF IN MILLIMETERS				
				CALCULATED			ESTIMATED 100 YEAR EXTREME		CALCULATED			ESTIMATED 100 YEAR EXTREME	
				MEAN	MAX.	MIN.	MAX.	MIN.	MEAN	MAX.	MIN.	MAX.	MIN.
1	THOMAS LAKE	23	2	-130	31	-540	175	-550	51	102	8	203	3
2	PARTRIDGE LAKE	4	0.3	-100	218	-470	275	-525	51	89	13	191	3
3	SHARPE LAKE	43	2	- 70	238	-440	320	-500	43	76	10	165	3
4	DROMORE LAKE	56	0.6	- 85	228	-455	300	-500	46	79	10	165	3
5	ECHO LAKE	77	9	- 70	190	-464	300	-480	127	178	25	229	13
6	NUMRO LAKE	78700	4	- 70	190	-464	300	-480	211	373	89	381	76
7	HORSESHOE LAKE	14	4	- 70	190	-464	300	-480	127	191	25	229	13
8	MEDITATION LAKE	6	2	- 70	190	-464	300	-480	127	203	25	241	13
9	MUD TURTLE LAKE	10	2	- 70	190	-464	300	-480	114	191	25	229	13
10	GEORGE LAKE	86	13	- 60	200	-450	325	-470	127	178	25	229	13
11	CROWDUCK LAKE	106	35	- 41	219	-440	350	-460	127	178	25	229	13

Appendix II(b)

Manitoba

Memorandum

Date January 13, 1986

To Al Beck
Env. Officer
Water Standards and Studies

From Mark Bennett
Special Projects Coordinator

Telephone

Subject: YOUR REQUEST FOR INFORMATION/DATA ON DRY DEPOSITION OF PHOSPHORUS

1) BACKGROUND

I shall not go into a lot of detail here about dry deposition mechanisms. To be perfectly honest, I cannot claim perfect understanding of the phenomenon. However, basically, the process of deposition (net flux) is defined by the following equation;

flux (mass/area/time) = Aerosol concentration (mass/volume*) X deposition velocity (length*/ time)

* the units for length and volume should be the same.

The deposition velocity when calculated involves several variables, including i) Particle or gas
ii) Physical characteristics (i.e., particle size distribution)
iii) Chemical characteristics (solubility, reactivity etc)
iv) Receptor surface characteristics
v) Meteorological conditions (most importantly wind speed)

On Wednesday, January 8, I spoke to Len Barrie (of Atmospheric Environment Service), who is an expert, and he estimated that the deposition velocity for Phosphate (PO_4) would not be much different than Sulphate (SO_4). Thus, velocities would range from about .1 to 2 cm/sec. Taking particle size distribution into account our best bet would be about .8 cm/sec.

From the data, obtained in Brandon and provided by Don Regehr we find the following;
i) Range of air phosphate concentrations = 0.01 - 0.4 $\mu g/m^3$
ii) Geometric mean concentration = 0.02 $\mu g/m^3$ (n= 18)
NOTE: The distribution of air-borne particulate concentrations is log-normal and, therefore, a geometric mean as opposed to an arithmetic mean, is calculated.
iii) Sampling took place between June 6 - October 4, 1985 and thus occurred during the open-water season.

../2

Al Beck
Page 2
January 13, 1986

2) PREDICTED DEPOSITION LEVELS

The following values represent the predicted dry deposition amounts, based upon the information above.

	PO_4	P*
Minimum value of annual deposition =	0.9 $mg/m^2/yr.$	0.3 $mg/m^2/yr.$
Maximum value of annual deposition =	250 $mg/m^2/yr.$	82 $mg/m^2/yr.$
Mean value of annual deposition =	5.0 $mg/m^2/yr.$	1.6 $mg/m^2/yr.$

P* - Phosphorus concentrations = Phosphates (PO_4) X 0.326

I hope this information is suitable for your purposes and meets your requirements.

Mark Bennett

MB/lp

cc: D. Regehr
D. Bezak

STATION MS0926, SOURCE - OTTER LAKE
SAMPLING LOCATION - N END LATITUDE 50:31 LONGITUDE 099:50

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	450.0	350.	340.	12.	8.15	186.	227.	0.	0.
86 07 15	440.0	330.	320.	8.	8.00	182.	222.	0.	0.
86 07 22	442.0	370.	350.	20.	8.25	182.	222.	0.	0.
86 07 29	406.0	340.	310.	32.	8.55	162.	183.	7.	0.
86 08 06	397.0	400.	360.	38.	8.50	162.	188.	5.	0.
86 08 12	389.0	390.	330.	64.	8.65	166.	178.	12.	0.
86 10 15	413.0	400.	320.	76.	8.45	162.	193.	2.	0.
87 01 12	730.0	560.	550.	13.	7.55	320.	390.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	46.	22.	205.	0.04	0.03	11.	7.	7.3	5.00
86 07 15	48.	23.	212.	0.05	0.04	10.	6.	5.7	4.00
86 07 22	49.	24.	220.	0.05	0.02	9.	7.	7.0	3.00
86 07 29	46.	23.	210.	0.08	0.03	10.	7.	7.5	6.50
86 08 06	42.	23.	198.	0.11	0.04	10.	7.	7.1	3.50
86 08 12	48.	25.	223.	0.13	0.05	10.	8.	8.3	5.00
86 10 15	57.	26.	250.	0.20	---	10.	8.	8.2	17.00
87 01 12	83.	46.	395.	1.17	0.14	17.	13.	0.1 L	9.30

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	17.0	2.20	0.66	0.02	0.055	3.	7.0	0.90	0.30
86 07 15	22.0	2.60	0.94	0.06	0.060	3.	6.3	0.90	0.00
86 07 22	25.0	2.40	0.09	0.22	0.100	3.	9.3	0.50	0.00
86 07 29	28.0	2.50	0.01	0.01 L	0.010 L	3.	6.5	0.40	0.00
86 08 06	30.0	2.50	0.02	0.01 L	0.120	3.	14.9	0.30	0.50
86 08 12	32.0	3.30	0.02	0.01 L	0.130	3.	83.5	0.30	0.00
86 10 15	28.0	4.20	0.03	0.01 L	0.250	3.	---	---	1.00
87 01 12	47.5	3.65	0.79	0.01 L	0.150	6.	---	---	0.60

STATION WQ0927, SOURCE - OTTER LAKE
SAMPLING LOCATION - MIDDLE LATITUDE 50:30 LONGITUDE 099:50

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	441.0	340.	330.	7.	8.15	180.	220.	0.	0.
86 07 15	427.0	320.	310.	16.	8.45	186.	217.	5.	0.
86 07 22	415.0	360.	330.	28.	8.70	170.	189.	10.	0.
86 07 29	380.0	330.	290.	38.	8.70	150.	163.	10.	0.
86 08 06	374.0	380.	340.	38.	8.70	152.	161.	12.	0.
86 08 12	376.0	370.	310.	64.	8.80	152.	146.	19.	0.
86 10 15	401.0	390.	320.	72.	8.50	158.	180.	2.	0.
87 01 12	620.0	510.	500.	13.	7.55	242.	295.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	45.	21.	199.	0.04	0.03	11.	7.	8.3	4.00
86 07 15	48.	23.	213.	0.05	0.08	9.	6.	8.1	6.00
86 07 22	47.	23.	212.	0.05	0.02	10.	7.	9.5	5.50
86 07 29	42.	23.	201.	0.08	0.03	10.	7.	7.1	3.50
86 08 06	41.	23.	197.	0.11	0.03	10.	7.	8.5	3.50
86 08 12	43.	24.	206.	0.10	0.04	10.	7.	9.6	5.50
86 10 15	47.	26.	225.	0.14	0.14	10.	8.	9.8	12.00
87 01 12	64.	40.	323.	0.44	0.06	17.	12.	0.2	5.60

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	17.0	2.60	1.20	0.02	0.065	3.	7.7	0.60	0.20
86 07 15	17.0	2.40	0.40	0.16	0.060	3.	5.6	0.70	0.40
86 07 22	22.0	2.40	0.06	0.01	0.105	3.	12.2	0.40	1.00
86 07 29	25.0	2.60	0.01	0.01 L	0.010 L	3.	12.5	0.30	0.20
86 08 06	27.0	2.30	0.01	0.01 L	0.120	3.	3.5	0.30	0.40
86 08 12	28.0	3.20	0.02	0.01 L	0.120	3.	52.2	0.20	0.40
86 10 15	28.0	4.30	0.01	0.01 L	0.240	3.	---	---	1.00
87 01 12	43.5	3.20	0.45	0.01 L	0.070	6.	---	---	0.60

STATION WQ0928, SOURCE - OTTER LAKE
SAMPLING LOCATION - N END LATITUDE 50:30 LONGITUDE 099:51

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	433.0	340.	330.	10.	8.35	182.	220.	1.	0.
86 07 15	424.0	320.	310.	12.	8.60	182.	205.	8.	0.
86 07 22	401.0	340.	320.	37.	8.70	164.	181.	10.	0.
86 07 29	375.0	340.	300.	37.	8.65	148.	161.	10.	0.
86 08 06	375.0	390.	350.	38.	8.75	150.	163.	10.	0.
86 08 12	370.0	370.	300.	66.	8.55	148.	151.	14.	0.
86 10 15	400.0	380.	310.	70.	8.45	162.	193.	2.	0.
87 01 12	610.0	500.	480.	15.	7.55	240.	293.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	46.	22.	206.	0.07	0.04	11.	7.	8.5	4.50
86 07 15	49.	23.	216.	0.07	0.05	11.	6.	9.5	4.00
86 07 22	45.	23.	207.	0.06	0.02	10.	7.	10.7	10.00
86 07 29	40.	23.	195.	0.08	0.04	10.	7.	8.2	3.00
86 08 06	40.	24.	197.	0.09	0.04	10.	7.	9.1	4.00
86 08 12	43.	25.	208.	0.11	0.05	10.	7.	9.1	10.00
86 10 15	44.	25.	214.	0.12	0.12	11.	8.	11.6	17.00
87 01 12	64.	39.	319.	0.34	0.06	17.	12.	0.1	4.30

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	17.0	2.60	0.92	0.02	0.080	3.	11.2	0.60	1.50
86 07 15	17.0	2.40	0.51	0.07	0.060	3.	7.0	0.70	1.90
86 07 22	21.0	2.90	0.02	0.01 L	0.110	3.	13.9	0.40	0.80
86 07 29	24.0	2.50	0.01	0.01 L	0.010	3.	10.0	0.40	0.60
86 08 06	24.0	2.70	0.01	0.01 L	0.110	3.	13.9	0.30	1.30
86 08 12	27.0	3.50	0.03	0.01 L	0.085	3.	83.5	0.20	0.20
86 10 15	28.0	4.10	0.01	0.01 L	0.240	3.	---	---	1.40
87 01 12	42.5	3.65	0.60	0.01	0.175	6.	---	---	0.20

STATION EM0969, SOURCE - OTTER LAKE
SAMPLING LOCATION - MID NORTH ARM LATITUDE 50:31 LONGITUDE 99:50

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	443.0	340.	330.	9.	8.10	182.	222.	0.	0.
86 07 15	443.0	320.	310.	8.	7.90	184.	224.	0.	0.
86 07 22	430.0	360.	340.	22.	8.50	178.	203.	7.	0.
86 07 29	390.0	340.	310.	32.	8.65	158.	178.	7.	0.
86 08 06	384.0	420.	370.	52.	8.50	156.	181.	5.	0.
86 08 12	393.0	370.	310.	56.	8.70	160.	166.	14.	0.
86 10 15	406.0	300.	310.	66.	8.50	164.	195.	2.	0.
87 01 12	433.0	550.	540.	12.	7.65	270.	329.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	46.	22.	206.	0.04	0.02	10.	7.	7.0	3.00
86 07 15	49.	23.	217.	0.04	0.04	10.	7.	4.9	3.50
86 07 22	49.	24.	221.	0.04	0.02	10.	7.	8.9	2.50
86 07 29	45.	23.	208.	0.08	0.03	10.	7.	9.5	5.00
86 08 06	43.	24.	205.	0.17	0.05	10.	7.	5.6	4.50
86 08 12	45.	25.	215.	0.12	0.04	10.	7.	8.7	4.50
86 10 15	48.	26.	227.	0.12	0.11	11.	8.	11.3	16.00
87 01 12	72.	44.	361.	0.35	0.06	19.	14.	3.3	5.70

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	18.0	2.80	1.40	0.01	0.060	3.	2.9	1.00	1.40
86 07 15	22.0	2.80	1.30	0.06	0.055	3.	3.5	1.00	1.30
86 07 22	25.0	2.50	0.07	0.14	0.110	3.	8.7	0.50	0.90
86 07 29	28.0	2.50	0.01	0.01 L	0.010 L	3.	5.0	0.40	0.80
86 08 06	30.0	3.20	0.02	0.01 L	0.140	3.	4.4	0.30	1.00
86 08 12	30.0	3.30	0.02	0.01 L	0.075	3.	76.6	0.30	0.20
86 10 15	20.0	3.90	0.02	0.01 L	0.240	3.	---	---	0.20
87 01 12	47.5	3.10	0.47	0.01 L	0.065	6.	---	---	0.40

STATION MQ0932, SOURCE - LITTLE JACKFISH LAKE
SAMPLING LOCATION - S END LATITUDE 50:29 LONGITUDE 100:05

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	966.0	790.	780.	10.	8.85	328.	334.	32.	0.
86 07 15	982.0	740.	730.	6.	8.75	336.	361.	24.	0.
86 07 22	994.0	790.	790.	5. L	8.70	332.	366.	19.	0.
86 07 29	998.0	770.	770.	5. L	8.70	326.	364.	17.	0.
86 08 06	978.0	820.	810.	8.	8.70	324.	346.	24.	0.
86 08 12	977.0	790.	780.	8.	8.75	334.	359.	24.	0.
86 10 15	1030.0	760.	760.	5. L	8.70	342.	378.	19.	0.
87 01 12	1140.0	920.	910.	14.	8.80	400.	425.	31.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	43.	97.	509.	0.02	0.02	27.	17.	8.5	1.00
86 07 15	45.	101.	528.	0.02	0.03	24.	17.	8.4	2.50
86 07 22	44.	103.	534.	0.02	0.02	29.	18.	6.3	0.95
86 07 29	44.	100.	521.	0.02	0.03	30.	18.	6.3	1.50
86 08 06	44.	101.	525.	0.02	0.03	29.	18.	9.5	1.00
86 08 12	46.	104.	543.	0.04	0.04	30.	18.	9.1	2.00
86 10 15	46.	104.	543.	0.02	0.05	28.	19.	11.1	2.00
87 01 12	50.	122.	626.	0.16	0.15	34.	24.	10.0	6.60

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	20.0	2.10	0.01	0.01 L	0.125	6.	8.4	0.75	0.90
86 07 15	22.0	2.20	0.01	0.01 L	0.140	6.	2.5	0.70	3.00
86 07 22	22.0	2.20	0.03	0.01	0.145	6.	7.0	1.00	2.60
86 07 29	24.0	2 00	0.03	0.01 L	0.015	7.	3.5	0.90	2.60
86 08 06	24.0	2.20	0.02	0.01 L	0.160	7.	7.7	0.60	0.40
86 08 12	24.0	2.10	0.01	0.01 L	0.160	7.	4.2	0.50	1.30
86 10 15	24.0	2.40	0.01	0.01 L	0.190	7.	---	---	1.00
87 01 12	20.0	2.70	0.01	0.01	0.160	9.	---	---	0.40

STATION MR0940, SOURCE - LITTLE JACKFISH LAKE
SAMPLING LOCATION - MIDDLE LATITUDE 50:29 LONGITUDE 100:05

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	971.0	780.	770.	9.	8.80	326.	344.	26.	0.
86 07 15	987.0	760.	750.	9.	8.75	336.	359.	25.	0.
86 07 22	994.0	810.	810.	5. L	8.70	334.	364.	22.	0.
86 07 29	973.0	760.	760.	5. L	8.75	322.	349.	22.	0.
86 08 07	978.0	850.	840.	10.	8.80	330.	354.	24.	0.
86 08 12	977.0	770.	760.	11.	8.75	334.	354.	26.	0.
86 10 15	1000.0	760.	750.	5.	8.70	346.	383.	19.	0.
87 01 12	1170.0	930.	920.	13.	8.45	404.	473.	10.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	43.	98.	509.	0.02	0.02	27.	17.	8.4	1.00
86 07 15	45.	100.	524.	0.02	0.05	23.	17.	7.7	4.50
86 07 22	44.	104.	538.	0.02	0.03	29.	18.	6.7	0.80
86 07 29	44.	101.	526.	0.02	0.02	30.	18.	6.2	0.75
86 08 07	45.	102.	531.	0.02	0.02	29.	18.	4.2	1.00
86 08 12	48.	108.	565.	0.02	0.03	29.	18.	9.3	0.80
86 10 15	46.	105.	548.	0.02	0.05	28.	20.	11.2	3.00
87 01 12	55.	121.	636.	0.07	0.06	34.	24.	4.2	12.50

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	20.0	2.10	0.00	0.01 L	0.125	6.	6.4	0.40	0.00
86 07 15	21.0	2.10	0.02	0.01 L	0.130	6.	5.5	0.70	4.20
86 07 22	22.0	2.10	0.04	0.01 L	0.145	6.	4.9	0.80	0.40
86 07 29	24.0	2.10	0.02	0.01 L	0.015	7.	3.5	0.80	1.70
86 08 07	24.0	2.10	0.02	0.01 L	0.150	7.	4.9	0.50	3.50
86 08 12	24.0	2.10	0.01	0.01 L	0.160	7.	4.9	0.70	0.00
86 10 15	24.0	2.30	0.01	0.02	0.180	7.	---	---	0.40
87 01 12	26.2	3.20	0.18	0.02	0.240	9.	---	---	0.00

STATION MQ0941, SOURCE - LITTLE JACKFISH LAKE
SAMPLING LOCATION - N END LATITUDE 50:29 LONGITUDE 100:05

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	976.0	780.	770.	11.	8.80	328.	342.	29.	0.
86 07 15	978.0	750.	740.	7.	8.80	330.	354.	29.	0.
86 07 22	984.0	790.	780.	6.	8.70	332.	361.	22.	0.
86 07 29	979.0	770.	760.	8.	8.60	322.	359.	17.	0.
86 08 06	978.0	830.	820.	10.	8.75	326.	339.	29.	0.
86 08 12	977.0	790.	780.	12.	8.70	336.	383.	26.	0.
86 10 15	1000.0	770.	770.	5. L	8.70	342.	373.	22.	0.
87 01 12	1190.0	940.	930.	10.	8.45	410.	481.	10.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	44.	97.	510.	0.02	0.03	23.	17.	6.8	1.50
86 07 15	45.	101.	527.	0.02	0.03	23.	17.	7.5	1.50
86 07 22	44.	103.	534.	0.02	0.02	29.	18.	9.8	1.00
86 07 29	44.	100.	520.	0.02	0.04	30.	18.	5.4	2.50
86 08 06	45.	103.	537.	0.02	0.02	29.	18.	10.3	0.90
86 08 12	48.	108.	564.	0.02	0.03	29.	18.	8.4	2.50
86 10 15	46.	104.	542.	0.02	0.05	28.	19.	12.1	7.50
87 01 12	56.	121.	638.	0.06	0.03	34.	23.	5.1	6.70

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	21.0	2.10	0.04	0.01 L	0.145	6.	6.3	0.90	1.50
86 07 15	21.0	1.90	0.01	0.01 L	0.125	6.	3.5	0.80	1.50
86 07 22	23.0	2.10	0.04	0.01 L	0.145	6.	5.6	0.90	0.00
86 07 29	24.0	2.10	0.01	0.01 L	0.010	7.	2.8	0.90	3.00
86 08 06	24.0	2.00	0.02	0.01 L	0.140	7.	4.2	0.70	0.60
86 08 12	24.0	2.00	0.01	0.01 L	0.160	7.	4.9	0.70	0.00
86 10 15	24.0	2.30	0.01	0.01 L	0.180	7.	-		1.00
87 01 12	28.2	3.05	0.04	0.01 L	0.245	9.	-		1.20

STATION WP0968, SOURCE - LITTLE JACKFISH LAKE
SAMPLING LOCATION - MID SOUTH END LATITUDE 50:29 LONGITUDE 100:25

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	957.0	790.	780.	8.	8.75	326.	344.	26.	0.
86 07 15	924.0	740.	740.	7.	8.75	336.	359.	25.	0.
86 07 22	979.0	780.	770.	6.	8.65	334.	368.	19.	0.
86 07 29	978.0	760.	760.	5. L	8.60	326.	364.	17.	0.
86 08 06	978.0	810.	800.	6.	8.45	328.	346.	26.	0.
86 08 12	977.0	770.	760.	10.	8.70	336.	361.	24.	0.
86 10 15	1000.0	770.	760.	5.	8.70	344.	376.	22.	0.
87 01 12	1170.0	920.	910.	11.	8.65	406.	447.	24.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	44.	97.	511.	0.03	0.14	23.	17.	7.9	2.00
86 07 15	45.	100.	523.	0.02	0.03	23.	17.	2.9	2.00
86 07 22	44.	103.	534.	0.02	0.02 L	29.	18.	6.6	0.70
86 07 29	44.	100.	410.	0.03	0.04	30.	18.	5.6	0.85
86 08 06	44.	101.	526.	0.02	0.03	29.	18.	10.5	0.75
86 08 12	46.	104.	542.	0.02	0.02	30.	18.	8.6	1.00
86 10 15	46.	104.	542.	0.02	0.05	27.	19.	11.4	2.50
87 01 12	53.	123.	630.	0.04	0.06	34.	24.	4.7	9.00

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	21.0	2.10	0.00	0.01 L	0.145	6.	7.7	0.75	4.00
86 07 15	21.0	2.10	0.01	0.01 L	0.130	6.	3.5	0.70	3.00
86 07 22	22.0	2.10	0.02	0.01 L	0.110	6.	5.6	0.90	0.00
86 07 29	23.0	2.10	0.03	0.01 L	0.010	7.	4.2	0.90	2.00
86 08 06	24.0	2.10	0.02	0.01 L	0.150	7.	4.2	0.60	0.50
86 08 12	24.0	2.10	0.02	0.01 L	0.170	7.	5.6	0.50	2.30
86 10 15	24.0	2.30	0.01	0.01 L	0.180	7.	---	---	2.00
87 01 12	20.0	3.10	0.01	0.01 L	0.230	9.	---	---	0.00

STATION WQ0942, SOURCE - SANDY LAKE
SAMPLING LOCATION - N E END LATITUDE 50:33 LONGITUDE 100:10

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	1420.0	1200.	1200.	7.	8.65	312.	342.	19.	0.
86 07 15	1440.0	1200.	1200.	6.	8.70	322.	349.	22.	0.
86 07 22	1440.0	1200.	1200.	6.	8.65	316.	342.	22.	0.
86 07 29	1430.0	1200.	1200.	5. L	8.70	308.	327.	24.	0.
86 08 06	1430.0	1200.	1200.	7.	8.75	316.	337.	24.	0.
86 08 12	1430.0	1200.	1200.	6.	8.70	322.	354.	19.	0.
86 10 15	1490.0	1200.	1200.	5. L	8.45	322.	383.	5.	0.
87 01 12	1690.0	1400.	1400.	5. L	8.15	370.	451.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	30.	147.	680.	0.06	0.03	35.	26.	7.5	2.00
86 07 15	32.	157.	726.	0.06	0.05	29.	25.	7.0	2.50
86 07 22	31.	162.	745.	0.07	0.05	41.	26.	8.3	0.85
86 07 29	31.	157.	724.	0.07	0.04	42.	26.	10.5	2.00
86 08 06	33.	164.	756.	0.05	0.04	41.	27.	10.0	1.00
86 08 12	34.	167.	772.	0.08	0.05	42.	27.	7.5	1.00
86 10 15	35.	156.	729.	0.02	0.04	37.	26.	9.5	1.60
87 01 12	43.	178.	908.	0.06	0.05	44.	33.	8.1	0.90

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	8.3	2.00	0.01	0.01 L	0.050	11.	1.0 L	1.25	3.10
86 07 15	8.6	2.00	0.02	0.01 L	0.040	11.	1.4	1.20	4.50
86 07 22	9.2	2.00	0.02	0.01 L	0.040	12.	2.1	1.30	0.50
86 07 29	10.0	2.00	0.02	0.01 L	0.010	12.	1.0 L	1.20	2.60
86 08 06	11.0	1.90	0.01	0.01 L	0.030	11.	1.4	1.80	0.00
86 08 12	12.0	2.00	0.04	0.01	0.035	12.	1.4	1.50	2.60
86 10 15	13.1	1.70	0.01	0.12	0.030	11.	---	---	0.00
87 01 12	14.6	2.35	0.15	0.14	0.025	14.	---	---	4.00

STATION WG0943, SOURCE - SANDY LAKE
SAMPLING LOCATION - MIDDLE LATITUDE 50:33 LONGITUDE 100:10

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	1420.0	1200.	1200.	7.	8.60	312.	349.	16.	0.
86 07 15	1430.0	1200.	1200.	5.	8.65	322.	354.	19.	0.
86 07 22	1440.0	1300.	1300.	6.	8.70	318.	349.	19.	0.
86 07 29	1420.0	1200.	1200.	7.	8.70	306.	329.	22.	0.
86 08 12	1410.0	1200.	1200.	6.	8.70	320.	351.	19.	0.
86 10 15	1480.0	1200.	1200.	5. L	8.45	328.	386.	7.	0.
87 01 12	1690.0	1400.	1400.	5. L	8.10	380.	464.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	31.	154.	710.	0.05	0.03	37.	25.	7.0	1.50
86 07 15	32.	158.	730.	0.06	0.05	38.	25.	8.4	2.00
86 07 22	31.	164.	753.	0.06	0.03	41.	26.	8.0	1.00
86 07 29	32.	161.	742.	0.07	0.04	42.	27.	6.6	1.00
86 08 12	35.	167.	773.	0.08	0.05	42.	28.	7.3	1.00
86 10 15	35.	156.	729.	0.02 L	0.03	37.	28.	8.9	1.40
87 01 12	43.	178.	841.	0.16	0.08	43.	33.	6.1	0.73

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	7.9	1.80	0.02	0.01 L	0.040	11.	2.6	1.25	4.80
86 07 15	8.5	1.90	0.02	0.01 L	0.035	11.	2.1	1.00	0.60
86 07 22	9.1	1.90	0.01	0.01 L	0.040	12.	2.8	1.20	2.40
86 07 29	10.0	2.00	0.02	0.01 L	0.015	12.	1.0 L	1.30	5.40
86 08 12	12.0	1.90	0.06	0.02	0.035	12.	2.1	1.00	0.60
86 10 15	13.2	1.70	0.01	0.12	0.035	11.	---	---	3.60
87 01 12	15.4	2.25	0.30	0.10	0.035	14.	---	---	4.90

STATION WQ0944, SOURCE - SANDY LAKE
SAMPLING LOCATION - S E END LATITUDE 50:32 LONGITUDE 100:10

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	1420.0	1200.	1200.	10.	8.65	312.	344.	18.	0.
86 07 15	1434.0	1200.	1200.	5. L	8.60	322.	354.	19.	0.
86 07 22	1440.0	1300.	1300.	8.	8.65	318.	344.	22.	0.
86 07 29	1440.0	1200.	1200.	5.	8.75	310.	334.	22.	0.
86 08 06	1430.0	1200.	1200.	5. L	8.70	312.	322.	29.	0.
86 08 12	1430.0	1200.	1200.	5.	8.65	318.	344.	22.	0.
86 10 15	1490.0	1200.	1200.	5. L	8.45	324.	381.	7.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	31.	155.	716.	0.06	0.04	35.	25.	8.3	1.50
86 07 15	32.	157.	726.	0.07	0.05	28.	25.	6.7	2.00
86 07 22	31.	163.	749.	0.07	0.04	41.	26.	7.5	10.00
86 07 29	33.	164.	757.	0.08	0.04	42.	27.	6.4	1.00
86 08 06	33.	164.	756.	0.05	0.04	41.	27.	9.0	1.50
86 08 12	35.	170.	787.	0.07	0.04	42.	26.	7.1	1.50
86 10 15	35.	155.	724.	0.02 L	0.03	35.	28.	9.9	1.00

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	8.3	1.80	0.01	0.01 L	0.040	11.	1.0 L	1.10	1.70
86 07 15	9.8	2.00	0.05	0.01	0.040	11.	2.8	1.10	4.40
86 07 22	9.2	2.00	0.02	0.01 L	0.040	12.	1.4	1.30	4.90
86 07 29	10.0	2.00	0.01	0.01 L	0.010 L	12.	1.0 L	1.30	1.10
86 08 06	11.0	2.10	0.02	0.01 L	0.032	11.	1.0 L	1.40	1.70
86 08 12	12.0	1.90	0.03	0.01	0.035	12.	1.0 L	1.70	3.30
86 10 15	12.7	1.70	0.01	0.11	0.030	11.	---	---	3.30

STATION MQ0966, SOURCE - SANDY LAKE
SAMPLING LOCATION - SOUTH NARROWS LATITUDE 50:33 LONGITUDE 100:10

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 07	1430.0	1200.	1200.	9.	8.60	312.	346.	17.	0.
86 07 15	1430.0	1200.	1200.	6.	8.65	322.	354.	19.	0.
86 07 22	1450.0	1300.	1300.	6.	8.65	316.	342.	22.	0.
86 07 29	1430.0	1200.	1200.	5.	8.70	314.	334.	24.	0.
86 08 06	1430.0	1200.	1200.	5. L	8.75	312.	322.	29.	0.
86 08 12	1430.0	1200.	1200.	6.	8.70	320.	346.	22.	0.
86 10 15	1480.0	1200.	1200.	5. L	8.40	324.	386.	5.	0.
87 01 12	1710.0	1400.	1400.	5. L	8.15	374.	456.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 07	31.	154.	711.	0.06	0.04	35.	25.	7.5	1.50
86 07 15	31.	156.	721.	0.06	0.05	30.	25.	8.1	2.00
86 07 22	32.	166.	763.	0.07	0.03	41.	26.	7.6	1.50
86 07 29	32.	161.	743.	0.07	0.04	42.	26.	7.9	2.00
86 08 06	32.	161.	742.	0.05	0.04	41.	27.	8.4	1.00
86 08 12	34.	170.	786.	0.08	0.06	42.	26.	6.5	0.90
86 10 15	35.	156.	728.	0.02 L	0.03	38.	28.	9.8	0.68
87 01 12	43.	179.	845.	0.08	0.05	44.	33.	6.9	1.11

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 07	8.1	1.90	0.02	0.01	0.040	11.	1.0 L	1.25	3.00
86 07 15	8.6	2.00	0.01	0.01 L	0.035	11.	1.0 L	1.20	2.40
86 07 22	9.2	1.90	0.01	0.01 L	0.040	12.	2.8	1.40	0.00
86 07 29	10.0	1.90	0.02	0.01 L	0.010 L	12.	1.4	1.20	1.00
86 08 06	11.0	1.90	0.02	0.01 L	0.030	11.	1.4	1.60	2.40
86 08 12	12.0	1.90	0.04	0.01	0.035	12.	2.8	1.50	4.00
86 10 15	12.8	1.80	0.01	0.12	0.030	11.	---	---	1.20
87 01 12	14.8	2.15	0.19	0.14	0.025	14.	---	---	3.50

STATION HR0957, SOURCE - BLUE (DUMMY) LAKE
SAMPLING LOCATION - S END LATITUDE 50:36 LONGITUDE 100:21

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	1520.0	1300.	1300.	8.	8.90	476.	478.	50.	0.
86 07 16	1540.0	1200.	1200.	5. L	8.75	486.	513.	38.	0.
86 07 23	1520.0	1200.	1200.	5. L	8.85	475.	472.	53.	0.
86 07 30	1500.0	1300.	1300.	5. L	8.95	470.	451.	60.	0.
86 08 07	1490.0	1300.	1300.	5. L	8.85	472.	493.	41.	0.
86 08 13	1500.0	1300.	1300.	5. L	8.85	470.	485.	43.	0.
86 10 15	1530.0	1300.	1300.	5. L	8.80	490.	515.	41.	0.
87 01 13	1640.0	1400.	1400.	5. L	8.65	526.	569.	36.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	21.	171.	756.	0.03	0.03	29.	40.	1.9	1.50
86 07 16	22.	181.	800.	0.05	0.08	26.	41.	3.2	1.50
86 07 23	21.	180.	792.	0.03	0.03	36.	42.	5.3	1.00
86 07 30	20.	171.	753.	0.03	0.05	37.	41.	6.2	1.50
86 08 07	19.	171.	752.	0.06	0.03	36.	39.	3.6	1.50
86 08 13	20.	175.	771.	0.05	0.03	35.	42.	4.0	1.50
86 10 15	22.	176.	776.	0.03	0.03	32.	45.	9.7	1.30
87 01 13	23.	184.	815.	0.03	0.05	36.	45.	8.7	0.93

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	0.4	2.00	0.02	0.01 L	0.029	8.	1.3	2.20	7.70
86 07 16	1.7	2.10	0.09	0.01 L	0.035	8.	1.0	2.10	8.40
86 07 23	0.6	2.10	0.03	0.01 L	0.035	7.	1.0 L	1.80	6.00
86 07 30	0.9	2.20	0.01	0.01	0.030	8.	1.0 L	2.60	9.00
86 08 07	2.0	2.20	0.03	0.01 L	0.035	8.	1.0 L	2.20	8.40
86 08 13	2.0	2.00	0.01	0.01 L	0.030	8.	1.0 L	2.20	8.40
86 10 15	2.7	2.20	0.08	0.03	0.035	8.	---	---	6.00
87 01 13	2.7	2.40	0.14	0.07	0.030	9.	---	---	0.00

STATION WQ0958, SOURCE - BLUE (DUMMY) LAKE
SAMPLING LOCATION - E END LATITUDE 50:36 LONGITUDE 100:21

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	1510.0	1300.	1300.	8.	8.85	470.	471.	50.	0.
86 07 16	1520.0	1300.	1300.	5.	8.85	486.	486.	53.	0.
86 07 23	1500.0	1300.	1300.	5. L	8.90	478.	466.	58.	0.
86 07 30	1500.0	1300.	1300.	5. L	8.90	470.	451.	60.	0.
86 08 07	1480.0	1300.	1300.	5. L	8.90	478.	471.	55.	0.
86 08 13	1490.0	1200.	1200.	5. L	8.95	470.	447.	62.	0.
86 10 15	1540.0	1300.	1300.	5. L	8.80	492.	517.	41.	0.
87 01 13	1660.0	1400.	1400.	5. L	8.65	528.	581.	31.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	21.	172.	760.	0.04	0.14	28.	41.	7.0	1.50
86 07 16	22.	185.	817.	0.03	0.06	26.	43.	8.4	1.00
86 07 23	20.	179.	788.	0.02	0.03	36.	42.	8.4	0.75
86 07 30	20.	174.	766.	0.02	0.05	37.	41.	5.1	1.50
86 08 07	20.	175.	770.	0.03	0.03	36.	39.	7.8	0.90
86 08 13	20.	171.	753.	0.02	0.03	36.	41.	5.9	0.95
86 10 15	22.	176.	778.	0.03	0.03	31.	45.	9.7	0.75
87 01 13	23.	183.	810.	0.04	0.05	36.	45.	6.4	1.30

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	0.6	2.10	0.02	0.01 L	0.035	8.	1.5	2.30	7.00
86 07 16	0.6	2.10	0.02	0.01 L	0.025	8.	1.5	1.80	2.60
86 07 23	0.6	2.10	0.01	0.01 L	0.030	7.	1.0 L	2.80	0.00
86 07 30	0.9	2.10	0.01	0.01 L	0.035	8.	1.0 L	2.10	0.90
86 08 07	1.2	2.10	0.01	0.01 L	0.025	8.	1.0 L	2.30	2.60
86 08 13	1.4	2.00	0.01	0.01 L	0.020	8.	1.1	2.40	0.00
86 10 15	2.6	2.10	0.08	0.03	0.040	8.	---	---	1.80
87 01 13	3.3	2.50	0.18	0.07	0.030	9.	---	---	8.00

STATION MR0959, SOURCE - BLUE (DUMMY) LAKE
SAMPLING LOCATION - M END LATITUDE 50:36 LONGITUDE 100:21

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	H.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	1500.0	1300.	1300.	10.	8.90	478.	476.	53.	0.
86 07 16	1520.0	1200.	1200.	5.	8.90	480.	478.	58.	0.
86 07 23	1510.0	1300.	1300.	5. L	8.90	478.	456.	62.	0.
86 07 30	1510.0	1300.	1300.	5. L	8.90	474.	471.	53.	0.
86 08 07	1480.0	1300.	1300.	5. L	8.90	468.	454.	58.	0.
86 08 13	1490.0	1300.	1300.	5. L	8.95	474.	451.	62.	0.
86 10 15	1540.0	1300.	1300.	5. L	8.80	490.	510.	43.	0.
87 01 13	1650.0	1400.	1400.	11.	8.65	526.	578.	31.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	21.	172.	760.	0.03	0.06	29.	40.	8.6	1.50
86 07 16	22.	183.	808.	0.03	0.05	25.	42.	9.2	1.00
86 07 23	19.	165.	725.	0.02	0.02 L	37.	40.	7.3	1.00
86 07 30	20.	171.	753.	0.03	0.04	37.	41.	6.2	1.50
86 08 07	20.	174.	765.	0.02	0.03	36.	40.	7.5	0.75
86 08 13	19.	168.	739.	0.03	0.03	35.	40.	8.5	0.90
86 10 15	21.	170.	754.	0.03	0.03	31.	46.	9.1	1.40
87 01 13	23.	184.	815.	0.04	0.05	35.	45.	8.6	1.50

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	0.6	3.00	0.01	0.01 L	0.033	8.	1.0 L	2.50	3.70
86 07 16	0.5	2.10	0.01	0.01 L	0.030	8.	1.5	1.90	2.80
86 07 23	0.6	2.20	0.01	0.01 L	0.030	7.	1.0 L	2.50	3.10
86 07 30	1.1	2.10	0.02	0.01 L	0.035	8.	1.0 L	2.00	1.80
86 08 07	1.2	2.10	0.01	0.01 L	0.030	8.	1.0 L	2.10	2.30
86 08 13	1.3	2.10	0.01	0.01 L	0.020	8.	1.0 L	2.30	2.40
86 10 15	2.6	2.20	0.08	0.03	0.045	8.	---	---	2.40
87 01 13	3.1	2.45	0.16	0.09	0.045	9.	---	---	6.00

STATION WQ0970, SOURCE - BLUE (DUMMY) LAKE
SAMPLING LOCATION - SOUTH BAY LATITUDE 50:36 LONGITUDE 100:21

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	1520.0	1300.	1300.	9.	8.80	478.	486.	48.	0.
86 07 16	1530.0	1300.	1300.	5.	8.90	438.	478.	58.	0.
86 07 23	1510.0	1300.	1300.	5.	8.90	473.	472.	53.	0.
86 07 30	1510.0	1300.	1300.	5. L	8.85	470.	451.	60.	0.
86 08 07	1490.0	1300.	1300.	5. L	8.85	476.	473.	53.	0.
86 08 13	1490.0	1300.	1300.	5. L	8.90	470.	466.	53.	0.
86 10 15	1540.0	1300.	1300.	5. L	8.85	490.	505.	46.	0.
87 01 13	1740.0	1500.	1500.	5. L	8.65	554.	612.	31.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	22.	176.	779.	0.05	0.04	28.	41.	7.9	2.00
86 07 16	23.	182.	806.	0.04	0.04	26.	42.	7.1	1.00
86 07 23	23.	178.	789.	0.06	0.04	36.	44.	6.6	1.50
86 07 30	20.	172.	759.	0.04	0.04	37.	41.	5.8	1.50
86 08 07	20.	174.	767.	0.04	0.03	35.	39.	7.3	0.80
86 08 13	20.	167.	736.	0.03	0.03	35.	40.	8.2	0.90
86 10 15	22.	176.	779.	0.03	0.04	32.	45.	10.8	1.10
87 01 13	25.	191.	848.	0.04	0.06	38.	48.	5.4	0.95

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	1.4	2.10	0.02	0.03	0.039	8.	1.0 L	2.10	3.30
86 07 16	1.2	2.10	0.02	0.01	0.025	8.	1.0	2.00	0.90
86 07 23	1.5	2.20	0.01	0.01 L	0.030	7.	1.0 L	2.10	3.20
86 07 30	1.7	2.20	0.01	0.01 L	0.030	8.	1.0 L	1.60	0.90
86 08 07	1.8	2.20	0.02	0.01 L	0.030	8.	1.0 L	1.80	0.90
86 08 13	1.6	2.10	0.01	0.01 L	0.020	8.	1.0 L	2.00	0.00
86 10 15	1.2	2.20	0.05	0.01	0.025	8.	---	---	2.20
87 01 13	2.0	2.55	0.32	0.07	0.025	10.	---	---	0.90

STATION W20948, SOURCE - STEWART LAKE
SAMPLING LOCATION - N END LATITUDE 50:38 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	717.0	580.	580.	5. L	8.55	176.	200.	7.	0.
86 07 16	727.0	540.	540.	5. L	8.55	184.	205.	10.	0.
86 07 23	728.0	560.	560.	5. L	8.55	176.	195.	10.	0.
86 07 30	722.0	560.	560.	5. L	8.60	176.	200.	7.	0.
86 08 07	704.0	540.	540.	5. L	8.45	178.	203.	7.	0.
86 08 13	711.0	540.	540.	5. L	8.55	174.	198.	7.	0.
86 10 15	723.0	530.	530.	5. L	8.45	182.	217.	2.	0.
87 01 13	829.0	630.	630.	5. L	8.00	210.	255.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	44.	64.	372.	0.07	0.03	14.	12.	8.6	1.50
86 07 16	46.	67.	390.	0.06	0.06	14.	12.	6.7	1.00
86 07 23	46.	67.	389.	0.06	0.03	16.	12.	8.4	1.50
86 07 30	42.	63.	366.	0.08	0.02	17.	12.	6.2	1.50
86 08 07	42.	63.	363.	0.15	0.02 L	16.	11.	2.8	1.00
86 08 13	47.	69.	394.	0.11	0.03	16.	12.	7.8	1.50
86 10 15	46.	67.	390.	0.03	0.02	16.	13.	9.1	1.80
87 01 13	53.	73.	430.	0.11	0.05	19.	14.	9.2	2.00

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	7.9	1.20	0.01	0.01 L	0.033	3.	3.1	2.00	1.30
86 07 16	7.8	1.20	0.03	0.01 L	0.035	3.	1.0	2.20	5.10
86 07 23	8.3	1.30	0.01	0.01 L	0.035	3.	2.0	2.60	3.20
86 07 30	8.5	1.40	0.02	0.01 L	0.060	3.	1.0 L	1.60	4.50
86 08 07	9.2	1.30	0.03	0.01 L	0.035	4.	2.5	1.70	5.10
86 08 13	9.1	1.30	0.02	0.01	0.040	5.	2.0	1.40	1.90
86 10 15	0.6	1.40	0.00	0.01 L	0.030	4.	---	---	2.00
87 01 13	2.5	1.50	0.22	0.04	0.025	6.	---	---	0.00

STATION WG0949, SOURCE - STEWART LAKE
SAMPLING LOCATION - MIDDLE LATITUDE 50:38 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	709.0	580.	580.	5. L	8.55	174.	198.	7.	0.
86 07 14	889.0	670.	670.	5. L	8.30	204.	249.	0.	0.
86 07 16	727.0	560.	560.	5. L	8.50	182.	207.	7.	0.
86 07 23	723.0	550.	550.	5. L	8.70	174.	193.	10.	0.
86 07 30	709.0	570.	570.	5. L	8.55	176.	200.	7.	0.
86 08 07	709.0	560.	560.	5. L	8.55	176.	200.	7.	0.
86 09 13	711.0	540.	540.	5. L	8.50	174.	198.	7.	0.
86 10 15	723.0	540.	540.	5. L	8.45	180.	215.	2.	0.
87 01 13	847.0	640.	640.	5. L	8.00	212.	259.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	44.	63.	370.	0.06	0.02	14.	11.	8.7	1.50
86 07 14	47.	77.	435.	0.05	0.02 L	20.	15.	8.7	0.55
86 07 16	45.	66.	385.	0.06	0.02	13.	11.	5.6	1.50
86 07 23	45.	67.	389.	0.05	0.02	16.	12.	7.5	1.00
86 07 30	43.	65.	373.	0.06	0.02	17.	12.	6.3	2.00
86 08 07	42.	63.	366.	0.09	0.02	16.	11.	4.7	1.00
86 08 13	47.	70.	400.	0.10	0.02	16.	13.	6.4	1.50
86 10 15	45.	66.	386.	0.03	0.02	16.	13.	11.0	1.30
87 01 13	55.	75.	447.	0.10	0.03	20.	14.	8.3	0.74

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	7.9	1.20	0.02	0.01 L	0.029	3.	1.7	2.25	0.00
86 07 14	15.0	1.50	0.12	0.02	0.020	4.	---	---	---
86 07 16	7.9	1.20	0.03	0.01 L	0.035	3.	1.0	2.30	3.60
86 07 23	8.0	1.40	0.01	0.01 L	0.040	3.	1.2	2.20	2.00
86 07 30	8.5	1.30	0.01	0.01 L	0.035	3.	1.0 I	1.40	3.40
86 08 07	8.8	1.30	0.01	0.01 L	0.025	4.	3.0	1.60	3.90
86 08 13	9.1	1.20	0.01	0.01 L	0.040	3.	3.5	1.50	1.00
86 10 15	8.8	1.20	0.01	0.01 L	0.035	4.	---	---	2.50
87 01 13	2.5	1.50	0.19	0.03	0.025	5.	---	---	2.30

STATION WH0950, SOURCE - STEWART LAKE
SAMPLING LOCATION - S END LATITUDE 50:38 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	714.0	600.	600.	5. L	8.55	176.	205.	5.	0.
86 07 14	912.0	680.	680.	5. L	8.35	212.	254.	2.	0.
86 07 16	709.0	540.	540.	5. L	8.70	176.	190.	12.	0.
86 07 23	721.0	550.	550.	5. L	8.60	174.	195.	8.	0.
86 07 30	704.0	560.	560.	5. L	8.60	170.	188.	10.	0.
86 08 07	704.0	550.	550.	5. L	8.45	179.	203.	5.	0.
86 08 13	711.0	550.	550.	5. L	8.60	172.	195.	7.	0.
86 10 15	726.0	540.	530.	6.	8.45	182.	212.	5.	0.
87 01 13	848.0	630.	630.	5. L	7.95	214.	261.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	44.	64.	372.	0.06	0.02	15.	11.	8.9	1.00
86 07 14	44.	74.	414.	0.63	0.02 L	20.	15.	9.6	0.75
86 07 16	46.	66.	397.	0.05	0.02	15.	12.	9.0	1.00
86 07 23	44.	65.	378.	0.05	0.02 L	16.	12.	8.5	1.00
86 07 30	41.	63.	360.	0.06	0.04	17.	12.	6.6	3.00
86 08 07	42.	63.	367.	0.08	0.02	16.	11.	7.3	1.00
86 08 13	46.	68.	393.	0.08	0.02	16.	12.	8.1	2.00
86 10 15	47.	67.	392.	0.04	0.12	16.	13.	11.2	2.50
87 01 13	55.	76.	448.	0.09	0.04	20.	14.	10.0	1.40

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	8.1	1.30	0.01	0.01 L	0.036	3.	2.6	2.20	1.90
86 07 14	15.0	1.50	0.09	0.01	0.020	4.	---	---	---
86 07 16	7.7	1.10	0.01	0.01 L	0.030	3.	1.0 L	2.40	1.50
86 07 23	8.3	1.30	0.02	0.01 L	0.030	3.	1.0 L	2.00	0.70
86 07 30	7.2	1.50	0.02	0.01 L	0.050	3.	1.4	1.10	2.60
86 08 07	8.4	1.30	0.01	0.01 L	0.030	4.	2.5	1.80	2.20
86 08 13	8.7	1.20	0.01	0.01 L	0.025	3.	1.5	1.40	0.70
86 10 15	0.8	1.20	0.01	0.01 L	0.030	4.	---	---	0.40
87 01 13	2.4	1.50	0.18	0.03	0.025	6.	---	---	1.60

STATION WQ0967, SOURCE - STEWART LAKE
SAMPLING LOCATION - SOUTH-WEST END LATITUDE 50:38 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	709.0	600.	600.	5. L	8.50	176.	205.	5.	0.
86 07 16	709.0	550.	550.	5. L	8.55	180.	200.	10.	0.
86 07 23	718.0	560.	560.	5. L	8.50	176.	203.	6.	0.
86 07 30	702.0	570.	570.	65.	8.55	174.	198.	7.	0.
86 08 07	704.0	550.	550.	5. L	8.50	178.	203.	7.	0.
86 08 13	711.0	530.	530.	5. L	8.55	172.	195.	7.	0.
86 10 15	721.0	530.	530.	5. L	8.50	182.	207.	7.	0.
87 01 13	842.0	660.	660.	5. L	8.05	212.	259.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	43.	63.	370.	0.07	0.05	16.	11.	8.8	1.50
86 07 16	46.	67.	388.	0.05	0.03	15.	11.	8.7	1.00
86 07 23	44.	66.	380.	0.09	0.02 L	16.	12.	6.7	0.75
86 07 30	42.	64.	367.	0.09	0.02	17.	12.	6.6	1.00
86 08 07	42.	63.	363.	0.10	0.02	16.	11.	7.6	0.80
86 08 13	47.	70.	406.	0.10	0.03	16.	13.	7.4	1.50
86 10 15	46.	67.	388.	0.03	0.03	16.	13.	11.2	2.50
87 01 13	55.	76.	448.	0.07	0.03	20.	14.	10.0	1.15

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	7.9	1.20	0.01	0.01	0.033	3.	3.5	2.00	1.00
86 07 16	7.8	1.10	0.01	0.01 L	0.030	3.	1.5	2.20	1.00
86 07 23	8.7	1.30	0.02	0.01 L	0.030	3.	1.5	2.20	4.50
86 07 30	8.6	1.30	0.01	0.01 L	0.035	3.	1.0 L	1.50	2.00
86 08 07	8.8	1.30	0.01	0.01 L	0.035	4.	2.0	1.50	2.00
86 08 13	9.3	1.10	0.00	0.01 L	0.035	3.	3.0	1.50	2.00
86 10 15	0.6	1.20	0.00	0.01	0.025	4.	---	---	0.50
87 01 13	2.2	1.50	0.17	0.03	0.030	6.	---	---	2.50

STATION WR0971, SOURCE - WOLF LAKE
SAMPLING LOCATION - NORTH END LATITUDE 50:29 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	806.0	620.	610.	8	8.40	224.	268.	2.	0.
86 07 16	819.0	600.	590.	7.	8.55	232.	259.	12.	0.
86 07 23	806.0	610.	610.	5. L	8.50	228.	256.	11.	0.
86 07 30	810.0	610.	610.	5. L	8.70	226.	249.	13.	0.
86 08 07	798.0	630.	630.	5. L	8.65	232.	244.	19.	0.
86 08 13	814.0	620.	610.	8.	8.70	226.	251.	12.	0.
86 10 15	825.0	610.	610.	5. L	8.45	234.	271.	7.	0.
87 01 13	1010.0	790.	790.	5. L	8.10	288.	351.	8.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	45.	66.	385.	0.09	0.04	23.	23.	7.9	3.00
86 07 16	49.	70.	410.	0.09	0.04	23.	24.	9.8	2.50
86 07 23	47.	67.	394.	0.08	0.03	27.	24.	8.1	1.00
86 07 30	44.	66.	383.	0.07	0.03	27.	24.	7.5	1.50
86 08 07	45.	67.	388.	0.07	0.04	26.	23.	7.8	1.50
86 08 13	46.	68.	395.	0.09	0.03	26.	23.	7.5	2.00
86 10 15	50.	73.	425.	0.05	0.06	25.	26.	10.7	2.00
87 01 13	59.	85.	495.	0.08	0.04	33.	30.	8.9	1.10

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NO3 + NO4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	6.3	1.70	0.05	0.01	0.070	5.	1.7	1.20	1.70
86 07 16	6.2	1.70	0.01	0.01 L	0.025	5.	3.5	0.80	1.80
86 07 23	6.9	1.90	0.01	0.01 L	0.075	4.	1.4	1.00	1.30
86 07 30	7.2	1.70	0.01	0.01 L	0.065	4.	2.8	0.40	0.00
86 08 07	7.4	1.80	0.01	0.01 L	0.065	4.	1.0 L	0.80	1.40
86 08 13	8.0	1.60	0.01	0.01 L	0.070	5.	2.1	0.40	2.70
86 10 15	11.1	1.90	0.01	0.01 L	0.060	4.	---	---	1.90
87 01 13	14.6	2.25	0.30	0.02	0.045	7.	---	---	2.10

STATION WQ0972, SOURCE - WOLF LAKE
SAMPLING LOCATION - CENTRAL BAY LATITUDE 50:29 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	H.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	798.0	610.	600.	8.	8.40	224.	268.	2.	0.
86 07 16	814.0	610.	610.	5. L	8.50	232.	254.	14.	0.
86 07 23	811.0	600.	600.	5. L	8.50	226.	254.	11.	0.
86 07 30	816.0	610.	610.	5. L	8.50	228.	261.	8.	0.
86 08 07	798.0	610.	610.	5. L	8.55	230.	256.	12.	0.
86 08 13	811.0	590.	580.	5.	8.65	224.	249.	12.	0.
86 10 15	825.0	600.	600.	5. L	8.40	236.	278.	5.	0.
87 01 13	905.0	750.	750.	5. L	7.80	278.	339.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	45.	65.	381.	0.09	0.03	22.	22.	4.3	2.00
86 07 16	48.	68.	401.	0.09	0.03	24.	23.	9.8	2.00
86 07 23	46.	66.	384.	0.08	0.02	27.	23.	7.9	0.85
86 07 30	45.	66.	387.	0.10	0.04	27.	24.	6.6	2.00
86 08 07	46.	68.	394.	0.08	0.02 L	26.	24.	6.7	1.50
86 08 13	46.	67.	393.	0.09	0.02	26.	24.	8.3	2.00
86 10 15	50.	73.	427.	0.05	0.08	25.	26.	10.7	3.00
87 01 13	57.	82.	480.	0.16	0.04	31.	29.	2.4	1.10

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	5.8	1.70	0.17	0.01 L	0.055	5.	1.0 L	1.30	4.50
86 07 16	5.8	1.60	0.01	0.01 L	0.060	5.	3.5	0.90	1.10
86 07 23	6.3	1.80	0.01	0.01 L	0.065	4.	1.4	1.10	2.00
86 07 30	7.0	1.70	0.01	0.01 L	0.075	4.	4.2	0.80	4.00
86 08 07	7.4	1.80	0.02	0.01 L	0.070	4.	2.1	1.10	4.00
86 08 13	8.2	1.70	0.02	0.01 L	0.080	5.	1.4	0.50	1.70
86 10 15	12.1	1.70	0.04	0.01	0.070	4.	---	---	3.70
87 01 13	15.6	2.35	0.64	0.03	0.050	7.	---	---	3.50

STATION WQ0973, SOURCE - WOLF LAKE
SAMPLING LOCATION - SOUTH NARROWS LATITUDE 50:29 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	F.R. MG/L	M.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	788.0	600.	590.	7.	8.45	226.	266.	5.	0.
86 07 16	806.0	590.	580.	7.	8.60	234.	261.	12.	0.
86 07 23	801.0	590.	590.	5. L	8.50	228.	259.	10.	0.
86 07 30	809.0	610.	610.	5. L	8.50	228.	264.	7.	0.
86 08 07	798.0	600.	600.	5. L	8.45	232.	273.	5.	0.
86 08 13	798.0	610.	600.	6.	8.70	230.	249.	16.	0.
86 10 15	829.0	610.	610.	5. L	8.30	232.	283.	0.	0.
87 01 13	1060.0	840.	830.	6.	8.05	310.	378.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	46.	64.	377.	0.09	0.03	25.	22.	9.5	2.50
86 07 16	48.	68.	400.	0.09	0.06	24.	23.	11.1	1.50
86 07 23	48.	67.	394.	0.09	0.02	27.	23.	8.0	1.00
86 07 30	46.	65.	379.	0.11	0.06	27.	23.	6.5	2.00
86 08 07	47.	67.	396.	0.12	0.02	26.	23.	7.0	1.50
86 08 13	49.	67.	397.	0.10	0.03	26.	23.	10.9	1.50
86 10 15	51.	73.	429.	0.03	0.07	25.	26.	11.1	1.50
87 01 13	65.	90.	533.	0.12	0.06	35.	32.	9.6	2.00

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO-A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	3.2	1.60	0.02	0.01 L	0.060	5.	3.5	0.40	1.20
86 07 16	5.4	1.60	0.01	0.01 L	0.060	5.	5.6	1.00	1.60
86 07 23	6.5	1.80	0.01	0.01 L	0.075	4.	3.5	1.00	1.60
86 07 30	7.8	1.90	0.01	0.01 L	0.105	4.	5.6	0.90	1.20
86 08 07	8.8	1.90	0.02	0.01 L	0.085	4.	4.9	0.60	0.50
86 08 13	10.0	1.70	0.01	0.01 L	0.080	5.	3.5	0.70	0.50
86 10 15	12.7	1.70	0.11	0.05	0.055	4.	---	---	0.90
87 01 13	16.8	2.60	0.44	0.04	0.085	7.	---	---	0.20

STATION WQ0974, SOURCE - WOLF LAKE
SAMPLING LOCATION - SOUTH-EAST BAY LATITUDE 50:29 LONGITUDE 100:16

FROM 86 06 01
TO 87 01 30

DATE	COND US/CM	T.R. MG/L	[illegible]	N.F.R. MG/L	PH PH UNITS	ALKALINITY MG(CACO3)/L	ALKALINITY MG(HCO3)/L	ALKALINITY MG(CO3)/L	ALKALINITY MG(OH)/L
86 07 08	780.0	610.	600.	8.	8.50	234.	266.	10.	0.
86 07 16	795.0	590.	580.	5.	8.45	240.	278.	7.	0.
86 07 23	790.0	580.	570.	5.	8.60	238.	266.	12.	0.
86 07 30	790.0	600.	590.	9.	8.60	238.	273.	8.	0.
86 08 07	795.0	620.	610.	10.	8.60	240.	268.	12.	0.
86 08 13	790.0	610.	600.	10.	8.75	236.	254.	17.	0.
86 10 15	824.0	620.	620.	5. L	8.15	230.	281.	0.	0.
87 01 13	1010.0	770.	770.	5. L	7.80	284.	347.	0.	0.

DATE	CALCIUM MG(CA)/L	MAGNESIUM MG(MG)/L	HARDNESS MG(CACO3)/L	MANGANESE MG(MN)/L	IRON MG(FE)/L	POTASSIUM MG(K)/L	SODIUM MG(NA)/L	DO MG(O2)/L	TURBIDITY NTU
86 07 08	48.	62.	375.	0.09	0.04	25.	21.	---	2.00
86 07 16	51.	65.	394.	0.12	0.07	24.	21.	4.2	2.00
86 07 23	51.	65.	397.	0.11	0.04	26.	23.	8.3	2.50
86 07 30	50.	64.	387.	0.10	0.06	27.	22.	6.6	3.50
86 08 07	48.	62.	373.	0.12	0.08	26.	21.	6.7	2.50
86 08 13	47.	61.	370.	0.09	0.03	26.	22.	7.7	4.00
86 10 15	51.	72.	423.	0.03	0.11	26.	25.	7.2	2.00
87 01 13	63.	84.	504.	0.15	0.06	32.	29.	3.9	1.70

DATE	SILICA MG(SIO2)/L	TKN MG(N)/L	NH3 + NH4 MG(N)/L	NO3-NO2 MG(N)/L	P-TOTAL MG(P)/L	CHLORIDE MG(CL)/L	CHLORO A UG/L	SECCHI DISC METRES	SAMPLE DEPTH METRES
86 07 08	6.9	1.80	0.03	0.01 L	0.090	5.	7.0	0.90	3.50
86 07 16	7.8	1.60	0.04	0.01 L	0.075	5.	7.0	0.80	4.00
86 07 23	8.7	1.80	0.02	0.01 L	0.110	4.	2.1	0.90	1.20
86 07 30	9.6	1.90	0.01	0.01 L	0.070	4.	3.3	0.80	1.20
86 08 07	10.0	1.90	0.01	0.01 L	0.100	4.	4.9	0.70	1.20
86 08 13	11.0	1.70	0.01	0.01 L	0.095	5.	5.6	0.50	2.50
86 10 15	13.3	1.50	0.03	0.07	0.055	4.	---	---	1.20
87 01 13	15.8	2.10	0.38	0.04	0.075	6.	---	---	1.20